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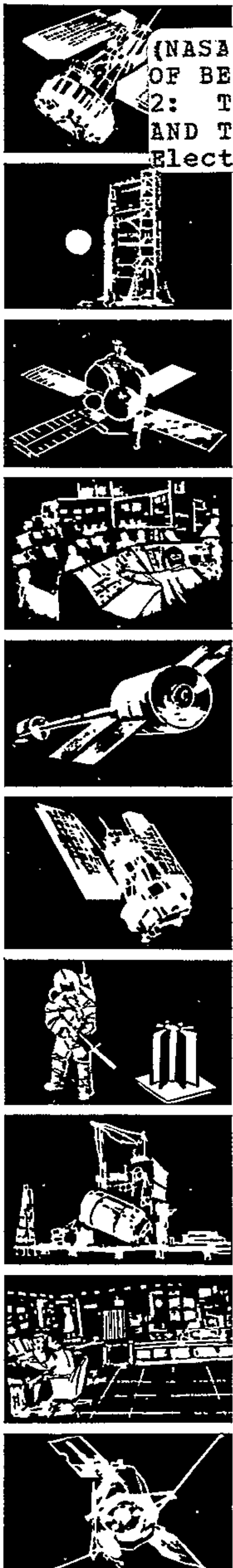

STUDY FOR IDENTIFICATION OF BENEFICIAL USES OF SPACE

(PHASE III)

FINAL REPORT

VOLUME II - TECHNICAL REPORT

BOOK 5 - STUDY METHODS AND TRADE STUDIES

CONTRACT NAS8-28179

NOVEMBER 30, 1975

SUBMITTED PER DPD #451,

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GENERAL ELECTRIC

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STUDY FOR

IDENTIFICATION OF

BENEFICAL USES OF SPACE (B.U.S.)

(PHASE III)

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TECHNICAL REPORT

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November 30, 1975

Submitted Per DPD #451, DR #MA-04

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PREFACE

The Final Report on Phase III of the Study for Identification of Beneficial Uses of Space (B. U. S.) is comprised of three volumes:

Volume I	Executive Summary
Volume II	Technical Report
Volume III	Appendices

Volume II is further subdivided:

Book 1 – Development and Business Analysis of Space Processed Isoenzymes

Book 2 – Development and Business Analysis of Space Processed Transparent Oxides

Book 3 – Development and Business Analysis of Space Processed Tungsten X-ray Targets

Book 4 – Development and Business Analysis of Space Processed Surface Acoustic Wave Devices

Book 5 – Study Methods and Trade Studies

General Electric's Space Division, under contract from the NASA's Marshall Space Flight Center completed Phase I of the Study in December 1972, and Phase II in December 1973. In Phase III, the Study has progressed to the Business Analysis and Planning for the commercial development and production of the four products in Phase II:

- Surface Acoustic Wave Components
- Transparent Oxides
- High Purity Tungsten X-ray Targets
- High Specificity Isoenzymes

The methodology employed in the Phase III Study and the results of that effort are reported herein.

In addition to Key Individuals from the participating User organizations who contributed specific product, process, business and planning data in each of their respective areas,

the Study Manager acknowledges the outstanding financial and manufacturing analysis contributions of Mr. P. Schmitt, and the considerable contributions of the following: Mr. U. Alvarado and Mr. M. Clarke of the Study Team in analyzing and organizing the wealth of data accumulated; Mr. K. Taylor, the MSFC Contracting Officers Representative (C.O.R.) for the study, in providing key technical suggestions and direction to the overall effort as well as establishing space processing payload guidelines, Mr. G. Wouch, Dr. E. Okress, and Dr. B. Noval of General Electric's Space Sciences Laboratory, in providing supporting space processing data, and Mr. B. Klawans and Mr. F. Curran of General Electric's Systems Operation and Computations Component in programming and processing "INVEST", the interactive profitability analysis program.

As noted in the Final Reports of earlier Phases, publication of this Phase III report neither implies NASA endorsement of any specific product, process or venture identified during this phase of the Study, nor a NASA commitment to pursue any program defined as part of this Study.

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SECTION I
INTRODUCTION

During the course of the Study, a number of key analyses were required, which involved combined aerospace/commercial disciplines and personnel from both communities.

In order to establish a mutually understandable methodology for such analyses the Study Team and Participating Users, and occasional consultants carried out initial dialogs followed by documentation of acceptable methods.

This book of the Technical Report, Volume II, presents such methods.

The first common ground for the combined disciplines was a Glossary of Terms, Section II. The glossary contained herein is heavily weighted with business terms, since the technical terms associated with Isoenzymes, Tungsten Processing, Surface Acoustic Wave Components, and Transparent Oxides have already been covered in Phases I and II.

Sections III and IV, Work Breakdown Structure, and Work Element Descriptions, Resource Needs, and Costs introduced some further formal baselines to the Study. The Generic Work Breakdown Structure of Section III was utilized to organize specific Structures for each product under study, each Structure containing both space and ground elements arrived at via mutual interaction.

The content of the Work Elements represented in the Work Breakdown Structure was formalized and kept uniform through use of the formats given in Section IV.

Section V, Concept Definition and Assessment, provided the Study Team and the Participants visibility of the limits and the organization of the efforts provided by both groups, spelling out where such efforts fit into the generation of processing concepts.

The example throughput analysis in Section VI was generated to demonstrate the need and method for such an effort. Throughput answers the question "How much material (time, power, etc.) must be put into a given Process Step in order to extract a given output?" When carried out for each sequential Process Step, over the total Process, working back from the final required output, we obtain the total Process cost-added factors, which enable calculation of Unit Cost. Section VII presents the outline of a typical method of forecasting the market for the products under study. The type of data required was not unfamiliar to the participants, but the long range (~10-17 years) of the required forecast is beyond the usual commercial product timing. The formats given in Section VII were developed to ease the generation of the required data.

Since a major portion of the cost of Space Processing will evolve from getting to "space", operating there, and returning, we developed a model for costing those portions of total programs for the four products under study. Section VII presents the Cost Model, and derives typical cost rates based on a nominal Shuttle/Spacelab average operating cost of $10.7 million per flight.

A key tool in this Phase of Study is the Financial Analysis Model, used to assess the profitability of the four products under study. The model, detailed in Section IX, is derived from standard future business venture analysis methods, and it has been computerized under the title "INVEST". The computerized model is discussed in Section IX, which also provides a sample business assessment questionaire used to initiate the business analysis.

SECTION II

GLOSSARY OF TERMS FOR PHASE III B.U.S. STUDY

This Glossary of Terms is issued to ensure a consistent usage of this terminology during Phase III B.U.S. Study. Comments and suggestions for additional terms to be included are welcome.

<u>(Approved) Charges</u>

Costs to the industrial organization for use of Shuttle/Spacelab as well as any other NASA facilities, equipment, materials and services, as approved by the NASA Contracting Officers Representative (COR) for use in this study.

<u>Benefits</u> (of space)

Economic or social gains resulting from a space manufacturing activity, and accruing to the space user or others.

<u>Business Plan</u>

An organized technical, financial, administrative and marketing plan for accomplishing a business objective (usually profit-oriented), based on stated assumptions and forecasts of future conditions and success in the venture.

<u>Cash Flow</u>

In general terms, a statement of the expected cash receipts and cash disbursements (inflow and outflow) of a business, along with the causes for these inflows and outflows, over a period of time.

Specifically, the cash flow accounts for all anticipated changes in assets and liabilities, including income, expenses, and changes in investments (cash, receivables, inventories, machinery and plant.)

When the cash flow statement reflects the present value of future cash, it is referred to as discounted cash flow.

Contributed Value (Added Value)

The portion of the market value of a product that each manufacturing step contributes to the product.

Cost/Benefit (Cost/Value)

The relationship between the costs of achieving a business objective and the economic or social gains to be obtained.

Depreciation

Writing off of a plant or equipment item cost as an expense over the life of the item according to business accounting practices and income tax laws.

Development Planning

The organization of technical, financial, and administrative data (including schedule, tasks, resources, contingencies, etc.) for developing a product to the stage where commercial production can begin (i.e., production designs and specifications are ready for release.)

Development Program

The performing of development activities in accordance with Development Planning.

Discounted Cash Flow

A statement of the cash flow of a business (see Cash Flow) which converts all future cash values to present worth for purposes of comparing one business opportunity with others. The discount factor is the estimated interest rate which money held today could earn if invested. (see Present Worth.)

Facilities

Buildings and major equipment items required for development or production. Includes ground-based buildings and equipment, drop towers, space-based facilities (such as Shuttle/Spacelab, automated spacecraft, aircraft, and sounding rockets), launch support facilities, and ground-based operations centers for space activities.

Flight Usage (Factor)

Measure of the degree of utilization of a Shuttle/Spacelab flight for a given experiment, test, or production run. (Used for equitable assessment of Shuttle/Spacelab operational costs to the user.)

Gross Margin

The difference between the cost of manufacturing a product and the selling price. Gross Margin includes profit, the cost of selling the item, and any other business expenses not covered in manufacturing costs. Same as "Mark-up."

Life Cycle

See Product Life Cycle.

Market

See Product Demand.

Market Analysis

The process of estimating product demand over time, product characteristics, product price, and market share for a supplier. (Used by the supplier to estimate sales, production requirements, product development requirements, financial plans, competitive methods and attractiveness of the venture.)

Market Share

That portion (percentage or quantity) of Product Demand (Market) which a particular supplier is able to convert to Orders and Sales. The remainder of the Product Demand is satisfied by other suppliers (competitors).

Mark-up

See Gross Margin

Materials

Any supplies or other items, (raw stock, components, etc.), purchased by a supplier for use in manufacturing his product. Excludes services.

Non-Space Activities

Ground-based activities required prior to, during, or after space manufacturing to produce a marketable item.

On-board Resources

Shuttle/Spacelab expendables used in space processing experiments, tests or production. Includes fuel cell fuels, attitude control propellant, atmosphere gasses, etc.

Orders

The dollar value (selling price times quantity) or quantity of a product for which the supplier has received firm commitments to buy from customers in a given time period.

Pilot Plant

Production line established to make a limited quantity of the product for evaluation of the product and the process. Pilot runs are usually made by the production department with engineering support. Extensive engineering tests may also be performed. As much production tooling and equipment is used as possible.

Present Value (Present Worth)

The value today of money expected to be received in the future, as defined by:

$$\text{Present Worth} = V_{today} = \frac{V\ future}{(1 + r)^t} \quad \text{(for single sum)}$$

Where r is the annual interest rate available over the time period and t is the number of years from now that the money will be received.

For example: a dollar expected one year from now is worth $0.91 today, if the available interest rate is 10%

$$V_{today} = \frac{1.00}{(1 + 0.10)^1} = \frac{1.00}{1.10} = .90909$$

Pricing

Establishing a selling price for a product which ensures that the customer will be motivated to buy the item and that the seller will be able to earn an acceptable profit after paying his expenses.

Process

For this Study, the total series of operations performed on the materials under study to convert them to marketable products.

Process Step

Each major operation performed on the material.

Product Demand

The current or forecasted quantity of a product that can be sold, based on a given set of product characteristics, product price, and market environment. Same as "Market."

Product Life Cycle

The time period extending from first commercial production of a product to termination of production (as caused by discontinued demand for the product). The life cycle typically passes through the following phases:

Phase	Sales Volume	Unit Price
Introduction	low, growing from zero	high, falling
Growth	intermediate, growing	intermediate, falling
Maturity	high, stable	low, stable
Decline	intermediate, falling	low, rising
Exit	low, falling to zero	low, rising

Program Plan

An overall plan for achieving a set of objectives, including schedules, tasks, staffing, facilities, finances, contingencies, etc. May consist of a number of supporting plans, such as Development Plan, Production Plan, Marketing Plan, Financial Plan, etc.

Prototype

A complete working model of an equipment or process line assembled for engineering laboratory tests and confirmation of development designs prior to establishment of pilot or routine manufacturing operations.

Resources

The money, manpower, facilities, equipment and supplies which a supplier needs to produce his products, including the development effort leading to a product.

Sales

The dollar value (selling price times quantity) or quantity of a product delivered to customers in a given time period. Sales are recorded at the time of passage of title of the product from seller to buyer- normally at date of delivery.

Scale-Up

Expansion of Pilot Plant operations to the intended full production capacity by addition of similar equipment, increasing duration of production run, increasing number of operating positions, etc.

Sensitivity Analysis

For this study, the process whereby the variables or assumptions used in determining costs, gross margins, and cash flows are varied about their nominal estimated values to determine the degree to which they affect the attractiveness of the business venture. (High sensitivity factors are key topics for further investigation.)

Services

Any assistance which a supplier purchases in order to implement his plans (e.g., for reasons of convienience, cost advantages, or the suppliers inability to perform the work himself.) Excludes Materials.

Supplier

Business organization which offers commercial products for sale at a profit. For this study, a "User" is a Supplier who takes advantage of the space environment for part of his manufacturing activities. (See User)

User (of Space Environment)

For this study, a commercial or government entity who makes use of the space environment for profit or equivalent economic/social gain. (See Supplier).

Work Breakdown Structure (W. B. S.)

A numbered list or diagram which depicts all the work elements required to carry out a program or plan such that all elements can be summed to a total for the program. The structure of the W. B. S. is designed to be compatible with the work elements, the major end-products, the performing organizational approach, funding allocations, cost retrieval requirements and scheduling requirements.

Work Element

A portion of the total work to be done, as defined by the Work Breakdown Structure. The description of a work element includes definition of the:

Inputs required to do the work

Outputs required by the work

Method of performing the work

Period of Performance (schedule)

Resources required

Assigned responsible person and organization.

SECTION III

GENERIC WORK BREAKDOWN STRUCTURE FOR SPACE DEVELOPMENT PROGRAMS (B. U. S., PHASE III)

The attached generic work breakdown structure and element definitions are established to guide the identification and planning of tasks for each of the 4 product areas in the BUS Phase III Study.

While the term "Work Breakdown Structure" is an aerospace term, the equivalent technique would probably be encountered in some form in commercial practice under terms such as "cost breakdown", "list of accounts", etc. The structure chosen for the WBS is a synthesis of aerospace elements and commercial production (process step) elements, so that it will probably appear both a little strange and a little familiar to the parties involved.

The basic rationale for the WBS is to 1) allow separation of R&D work from pilot/production work, 2) allow segregation of each process step so that its benefits and costs can be separately assessed and 3) assure that all steps and costs from raw materials to finished product are addressed, however lightly. A separate major WBS element is established for each process step (4.0, 5.0, etc.). To these process elements, the integrating functions (1.0 Program Management, 2.0 System Engineering, 3.0 Business Operations) are added. In aerospace contracts, Program Management and System Engineering are usually direct cost elements, while in commercial practice, they would be overhead accounts. Business Operations would be a general and administrative (G&A) account or equivalent in both aerospace and commercial practice.

Segregation of the process steps is useful in that the alternative of buying rather than in-house manufacturing can be considered for each process step. Also, the option of selling an intermediate product (as against the final product) can be examined.

Conventional hardware breakdown as employed in an aerospace WBS is established within each process step, in the Equipment Development and Test element.

Definitions of W.B.S. Elements

III.1 PROGRAM MANAGEMENT

This element includes the effort of the program manager, his staff, and the administrative support which is not specifically relatable to one of the product/process W.B.S. elements and which is required to manage the product area development and operations. Includes:

- Management Reports & Presentations
- Contract Administration
- Travel and Living Expenses Pool
- Secreterial Support Pool
- Program Schedule Control
- Program Cost Control
- Business Consultation Services
- Customer Liaison

III.1.1 PROGRAM MANAGEMENT - R&D Phase

This element includes all of the effort described in element 1.0 from program start to the point in time when a complete prototype process for all process steps has been achieved.

III.1.2 PROGRAM MANAGEMENT - PILOT/PRODUCTION PHASE

This element includes all of the effort described in element 1.0 from the ending point of element 1.1 (R&D Phase) until this activity is no longer required. The ending point of element 1.1 occurs when production activities have been reduced to proceduralized routines and the work can be performed by on-going Marketing Administration and Production Control functions.

III. 2 SYSTEM ENGINEERING

This element includes the product area system engineering design and analysis which is generally applicable to all process steps and the associated W. B. S. elements. Includes:

- Overall Process Flow Analysis
- Overall Process Requirements and Specifications
- Process Step Equipment Requirements
- Ground and Space Mission Analysis
- Interface Definition and Control
- Materials Requirements

III. 2. 1 SYSTEM ENGINEERING - R&D PHASE

This element includes all of the effort described in element 2. 0 from program start to the point in time when a complete prototype process for all process steps has been achieved.

III. 2. 2 SYSTEM ENGINEERING - PILOT/PRODUCTION PHASE

This element includes all of the effort described in element 2. 0 from the ending point of element 2. 1 (R&D Phase) until this activity is no longer required. The ending point of element 2. 2 occurs when production engineering activities have been reduced to following-engineering and product/process improvements which can be handled by Advanced Engineering and Manufacturing functions.

III. 3 BUSINESS OPERATIONS

This element includes the effort associated with defining, cultivating, and sustaining a new product in the marketplace, except as provided for in other W. B. S. elements. This activity is applicable to all product development phases and is defined by the following subelements.

III. 3. 1 BUSINESS OPERATIONS - R&D PHASE

This element includes the preparative and exploratory Marketing, Advanced Engineering and Administrative activities which occur between program start and the time of achievement of a prototype capability for the overall product/process, as defined in the following subelements.

III.3.1.1 Marketing

This element includes the effort required for market research, product planning, advertising, sales literature, customer product service, catalog issues, sales engineering, applications engineering, proposal efforts, etc. as required to introduce the new product and maintain an acceptable orders/sales profile throughout the product life cycle.

III.3.1.2 Advanced Engineering

This element includes the engineering effort (exclusive of initial development covered in other W.B.S. elements) required to establish and maintain a competitive product design. This element includes the engineering effort associated with patent applications and technical support of catalog and sales literature preparation.

III.3.1.3 Financial, Legal, and Relations Support

This element includes the financial, legal and personnel relations support required to introduce the new product. Legal support includes the filing of patent applications and obtaining of NASA service agreements, as well as any consultation services required for those items.

III.3.2 BUSINESS OPERATIONS - PILOT/PRODUCTION PHASE

This element includes the same activities as given in 3.1, beginning at the end of the R&D (prototype) phase and continuing for the duration of the production period.

III.4 PROCESS STEP (Each Process)

This element is defined as a set of manufacturing steps which are grouped because they constitute a ground or space "production line" in terms of location (space or ground), facility arrangements (e.g. space module), and design approach.

The product associated with the process may be an end-product for commercial use or an intermediate product or service which is ultimately used in an end-product.

This element includes all effort and materials required to proceed from initial feasibility investigations to ultimate commercial manufacturing operations for the particular process step.

III.4.1 PROCESS STEP - PROCESS AND EQUIPMENT DEVELOPMENT - R&D PHASE

This element includes all of the basic phenomenological investigations, process feasibility investigations, breadboard, preprototype and prototype fabrication and testing required to design and confirm the process methods and process equipment prior to initiation of a pilot/production facility.

III.4.1.1 Process Development

This element includes all of the process-oriented investigations and tests to be conducted in the R&D Phase, including project supervision of the process development effort. It also includes the establishment of equipment design requirements, via analysis or test, of specific equipment items to be developed in element 4.1.2, Equipment Development and Test.

III.4.1.1.1 Project Supervision

This element includes the project supervision and administrative effort required to conduct the process development effort for the particular process.

III.4.1.1.2 Ground Lab Studies

This element includes all of the analyses and tests required to investigate alternatives and design the required process, within the limitations of the ground environment. For ground-based processes, this would include the complete process test program. For space-based processes, additional testing in the space environment is required, as provided in elements 4.1.1.3 and 4.1.1.4.

III.4.1.1.3 Sounding Rocket/Drop Tower/KC-135 Tests

This element includes any preparations and tests which are needed to explore process or equipment design questions in a limited space flight mode, as made possible by

sounding rockets or KC-135 flights (zero-G trajectory), or drop tower applications. This element is not applicable to process steps which are ground-based or which do not benefit from the limited time duration of these test modes.

III.4.1.1.4 Shuttle Tests

This element includes any preparations and tests which are needed to establish and confirm prototype process and equipment designs and product characteristics via Space Shuttle/Spacelab services. Several process steps may be tested on one shuttle flight, either independently or together. Element 4.1.1.4 is not applicable to ground-based processes.

III.4.1.2 Process Step Equipment Deveopment and Test

This element includes the design and development effort to provide new equipment items needed for the prototype process step. Design requirements for this effort are developed in element 4.1.1. Whereas straightforward equipment adaptations can be made in element 4.1.1 as part of process development, element 4.1.2 provides for major equipment developments requiring design specialists and significant development effort. Examples might be a compact light-weight process control and instrumentation unit for in-space automated operation, a new in-space gas coolant system, a new manipulator, feed and retrieval apparatus, etc. In-space testing of such new equipments would be done as part of the process tests in element 4.1.1, or if complex, they might required separate additional tests in element 4.1.2. Subelements under 4.1.2 are the specific equipments to be developed.

III.4.2 PROCESS STEP - PILOT/PRODUCTION

This element begins when a management decision is made to proceed with production preparations for the particular process. It includes all of the effort required to apply prototype designs to production requirements, to achieve production start-up,

and to proceed with production for commercial purposes. Typically, a pilot facility of limited capacity is established prior to implementing full-scale production capacity.

III. 5, III. 6, etc. - ADDITIONAL PROCESS STEPS

(Same breakdown as in 4.0).

SECTION IV

INSTRUCTIONS FOR PREPARATION OF DEVELOPMENT TASK AND RESOURCE ESTIMATES - PHASE III

IV.1 PURPOSE

The following instructions for preparation of Development Task Descriptions are issued to collect the essential data for description of the Development Plan for each product area in the Phase III Study. The formats of the work sheets have been designed to simplify preparation efforts and to minimize the need for follow-up data gathering during the study.

IV.2 PREPARATION INSTRUCTIONS

The product development program will be defined as an organized collection of tasks, each of which is described by a task package. A task (for example, an experiment which is conducted in a series of runs) is described by completing the following forms which constitute a task package:

Form No.	Form Title
BUS-1	Task Description
BUS-3	Task Resources Requirements
BUS-2	Work Element (Task) Costs

Instructions for each form are given in the following paragraphs:

IV.2.1 TASK DESCRIPTION SHEET (BUS-1)

Task Title	-	Short, descriptive title to distinguish this task from other tasks.
WBS Element No.	-	Element in Work Breakdown Structure which this task is part of.
Required Output	-	Task results which are being sought (e.g., "Report on Selection of Masking Techniques").
Required Input	-	Information, etc. required to perform the task (e.g. "Shuttle Payload Constraints"; "Results of Experiment No. 8", etc.).

Description of Effort	-	Summary of work to be done (e.g. "Conduct an experiment to determine a preferred masking technique using a ground laboratory set-up with available equipment. Test 4 candidate techniques, compare results and select a preferred technique. Typical experiment sequence will be......etc.").
Performance Period	-	Duration of effort in days, weeks or months, and basis for start or end point (e.g. "6 weeks duration, starting at completion of Experiment No. 8").
Performance Responsibility	-	Who should perform the task (e.g. NASA, Shuttle Contractor, Study Contractor, Spacecraft Contractor, etc.).
Approval	-	Signature of person representing the organization preparing the task estimate.

IV.2.2 TASK RESOURCE REQUIREMENTS (BUS-3)

Task Title, WBS Element No.	-	(Same as in 2.1)
Labor	-	Type of person(s) required (e.g. Engineer, Technician, Specialists, etc.)
Purchased Materials	-	Brief description or list of supplies and raw materials.
Services	-	Brief description of outside services required.
Equipment	-	Brief description of items equipment to be procured or fabricated.
Facilities	-	Brief description of facilities usage or construction. (Type, square footage, build new, modify, lease, etc.).

IV.2.3 WORK ELEMENT (TASK) RESOURCE COSTS (BUS-2)

Task Title, WBS Element No.	-	(Same as in 2.1)
Activity No.	-	Serial numbering of the sub-elements of the task (i.e., 1, 2, 3 - etc.)
Labor Cost	-	Labor hours times labor rate per hour, where labor rate includes labor, overhead, and G&A.
Purchased Materials Cost	-	Supplies and raw materials cost through G&A.
Services Cost	-	Cost of outside services required.
Equipment Cost	-	Cost of procuring or fabricating equipment through G&A.
Facilities Cost	-	Cost of facility usage or construction.
Total Costs	-	Sum of columns 5, 6, 7, 8 and 9.

Notes:

1. All costs are engineering estimates in an accuracy proportionate to the level of understanding presently available.
2. All costs should be expressed in 1974 dollars (no allowance for inflation, etc.).

TASK DESCRIPTION

TASK TITLE		
WBS NO.	PREPARED BY	DATE

1. REQUIRED OUTPUT:

2. REQUIRED INPUT:

3. DESCRIPTION OF EFFORT:

4. PERFORMANCE PERIOD:

PERFORMANCE RESPONSIBILITY:	APPROVAL:

NOTE: CONTINUE NUMBERED ITEMS ON SEPARATE SHEET AS REQUIRED

BUS-1

TASK RESOURCE REQUIREMENTS

TASK TITLE		
WBS NO.	PREPARED BY	DATE
1. PURCHASED MATERIALS: (INCLUDE ASSUMPTIONS)		
2. PURCHASED SERVICES: (INCLUDE ASSUMPTIONS)		
3. EQUIPMENT: (INCLUDE ASSUMPTIONS)		
4. FACILITIES: (INCLUDE ASSUMPTIONS)		
	APPROVAL:	

NOTE: CONTINUE NUMBERED ITEMS ON SEPARATE SHEET AS REQUIRED.

BUS-3

WORK ELEMENT COSTS

WORK ELEMENT NO.	WORK ELEMENT TITLE

1 ACT. NO.	2 ACTIVITY	3 LABOR COST	4 PURCHASED MATERIALS COST	5 SERVICES COST	6 EQUIPMENT COST	7 FACILITIES COST	8 TOTAL COST
	TOTALS						

SECTION V

CONCEPT DEFINITION & ASSESSMENT METHOD

V.1 BUSINESS CONCEPT

The B.U.S. Phase III Study has as one of its objectives, the financial assessment of 4 product candidates in terms of business viability. At the beginning of the study, virtually none of the information on which such an assessment could be based was available, so that a framework has been sought for conceptually establishing a useful data base. As shown in Figure 1, there are many questions or factors which a businessman might consider in looking at investing in a space venture. The factors to the right in the diagram, although very real concerns, were excluded from the concept definition model, on the basis that these factors would enter in when, and if, the venture could be shown to have promise based on the operational factors (left side of diagram).

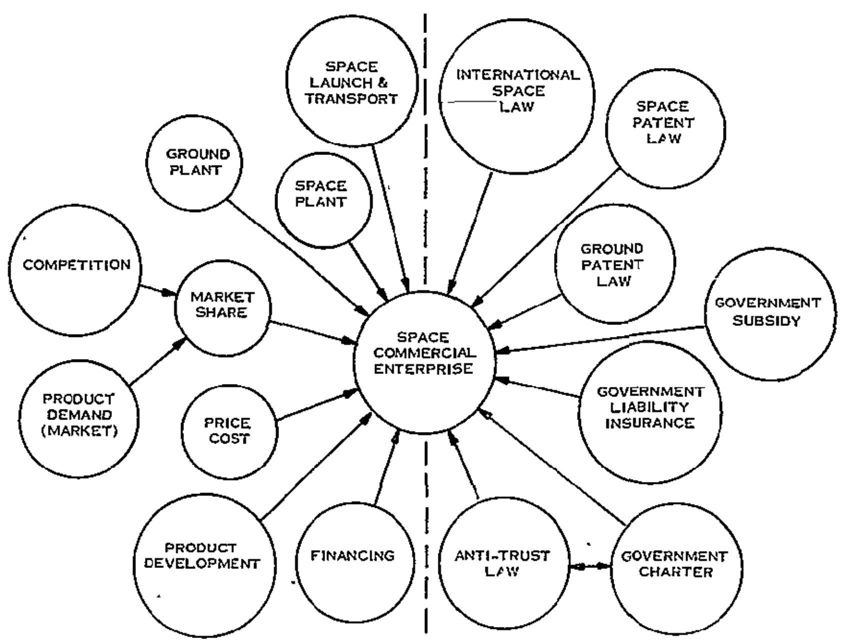


Figure 1. Factors involved in the Space Commercial Enterprise

V.2 ECONOMIC ANALYSIS

Since the development (R&D) program necessarily must lead to a prototype manufacturing capability, the question of what this prototype capability should be has to be addressed from the beginning of the study.

Thus, concurrent with the definition of development tasks (as an extension of Phase II preliminary task definitions), an iterative exercise has been conducted to examine the economic feasibility of the product/business (Figure 2). The results of this iterative exercise for all 4 products fairly well describe the problem and give a number of insights into the financial burdens of space processing. In all cases, the initial unit price required was higher than is desired, and the major contributing costs could be identified. The impact of space service charges and the need for a low-cost in-space power source were conspicuous in this exercise.

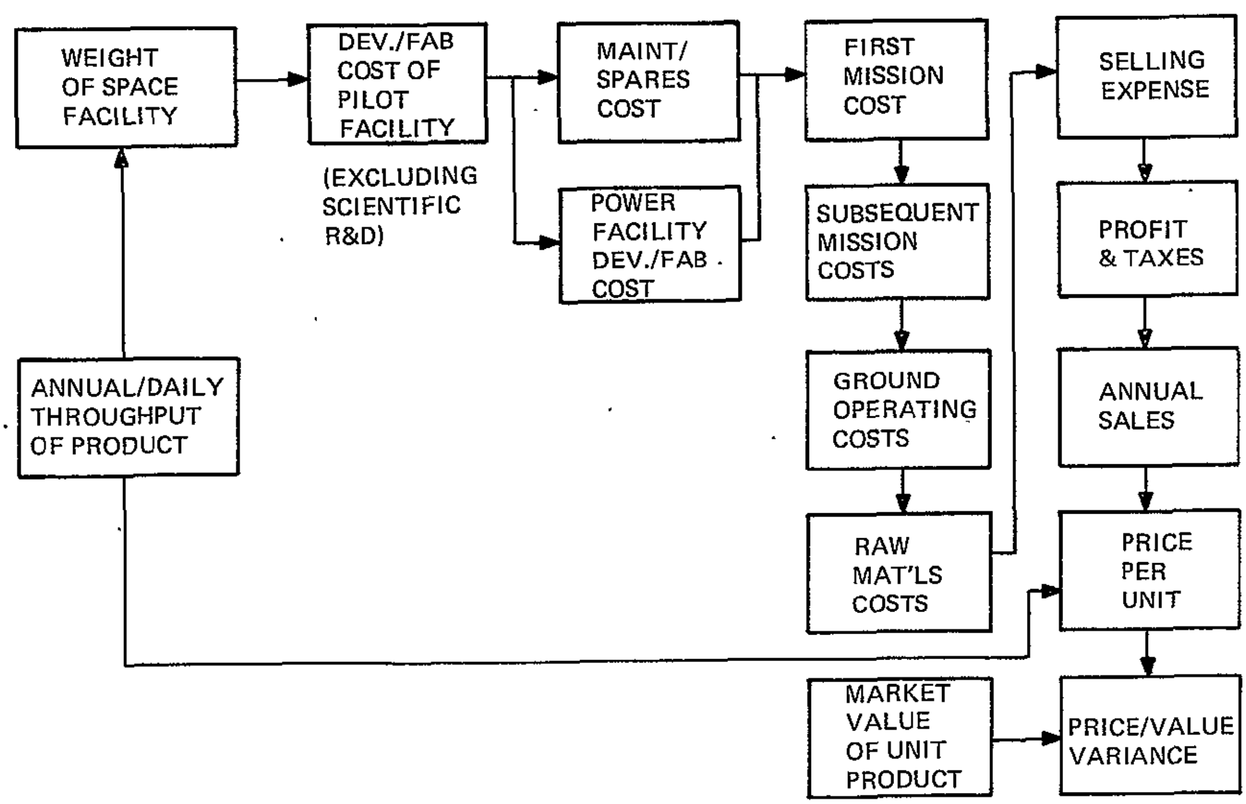


Figure 2. Rationale for Determining Preliminary Economic Feasibility

Although an in-depth study of space power was beyond the scope of the study, consultation with key workers in that field provided us with ROM estimates of projected energy costs for various power generation methods. Figure 3 summarizes those estimates. For this study, a conservative cost of power for production use in space was established at $40 per KWH. It appears that such a figure could be achieved, and it has been assumed in the study that such service from a power source of appropriate capacity would be made available by the space support agency (NASA or others).

V.3 PROCESS AND THROUGHPUT EVALUATION

At this point, a dialogue was established with each of the 4 study contributors, to explore the factors involved in the preliminary economic analysis. A baseline ground/space process was defined and a throughput analysis was made to establish a detailed understanding of the workload, materials, process equipment, and process shrinkages involved in a given output. The throughput requirement at this time was a conjectural number taken to be in the realm of the eventual business volume to be handled.

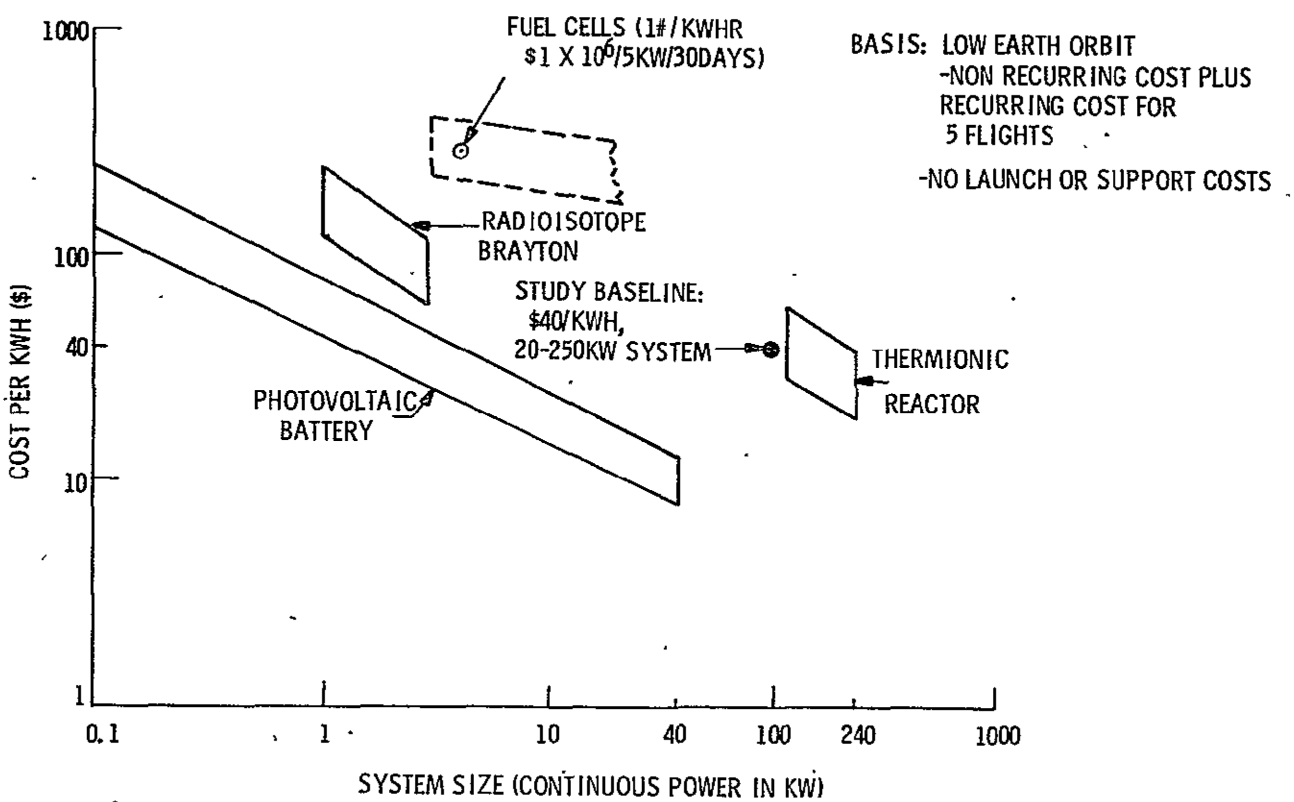


Figure 3. Comparative Costs of Power in Space

V.4 DEVELOPMENT PLAN

Meanwhile, the definition of the development program tasks proceeded (Figure 4) using the insights gained from the process, throughput, and preliminary economic feasibility assessment. The Work Breakdown Structure was initially based on the several process steps required to achieve the end product, and, as the study progressed, this approach continued to appear the best. The business assessment findings continued to interact with the development program throughout the study, an example being the case where a too-expensive in-space process step was changed to a ground step, with resultant simplification of the development task. The study scope did not permit any optimization efforts, so the planning was addressed to finding a single reasonable baseline approach on which all assessments could be based. In general, the R&D program for each product is long and expensive, and future study efforts should explore means of compressing the time scale and reducing (or finding ways to share) the process development costs. The number of R&D flights required

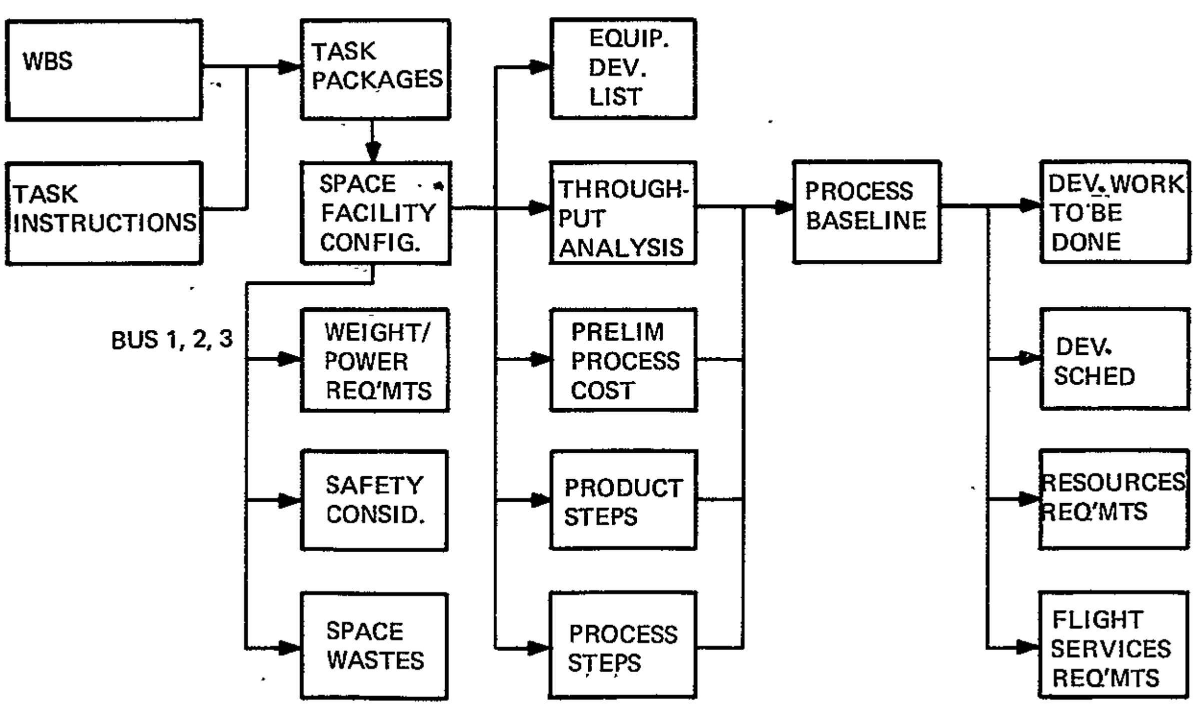


Figure 4. Development Planning Methodology (Task 1)

(sounding rocket, KC-135, shuttle) was a rough estimate also, and this area, one of high cost, must be examined in the future. In most cases, the process equipment requirements remained in conceptual form throughout the study, but process development tasks were estimated to include these development costs as far as possible. However, an element of the Work Breakdown Structure (Equipment Development) has been provided within each process step, for later distinction between process development and equipment development tasks.

V.5 MARKET ASSESSMENT

The market assessment, Figure 5, was performed by the study contributors in response to a questionnaire which solicited an estimate for each of the items in the figure. The product description was fairly well understood, from previous economic analysis and throughput analysis. The product demand, price and product life cycle generally were difficult to assess in the time available, and these areas must be addressed in detail in the future. Also the figures estimated for use as baselines in the study must be used with caution.

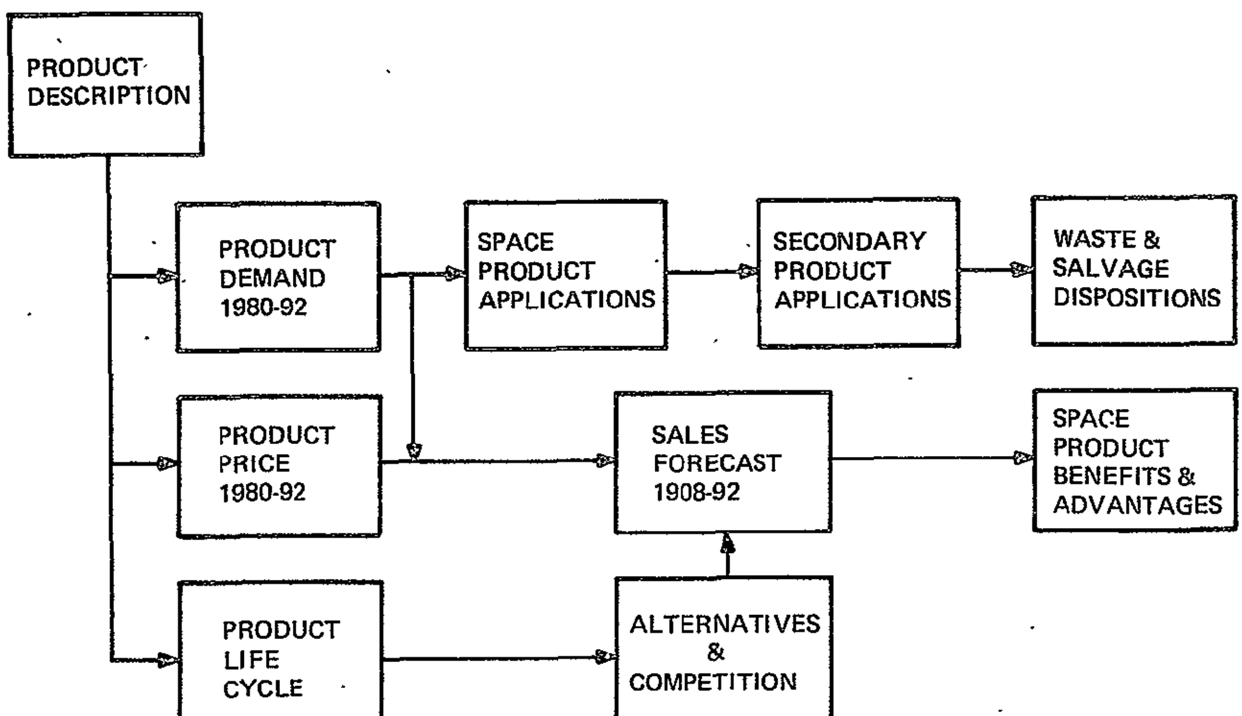


Figure 5. Market Assessment Methodology (Task 1)

V.6 BUSINESS PLANNING

A summary of the business planning method is shown in Figure 6. An intention from the beginning of the study was to attempt the generation of a time-profiled financial forecast for each product/business, and to do this in a simple, yet realistic manner, similar to that used in assessment of business ventures by General Electric. The financial model established to accomplish this is such that manual forecasts can be made of single cases. For case iterations, sensitivity analysis, and calculation of present value, the INVEST computer routine was used (described separately under Financial Model).

The data obtained from the market assessment and R&D program estimate were used as data inputs, as well as estimates of unit manufacturing (shop) cost and annual plant and equipment. Subsequent calculations were based on percentage factors for items such as selling expense, administration expense, etc. The baseline percentages

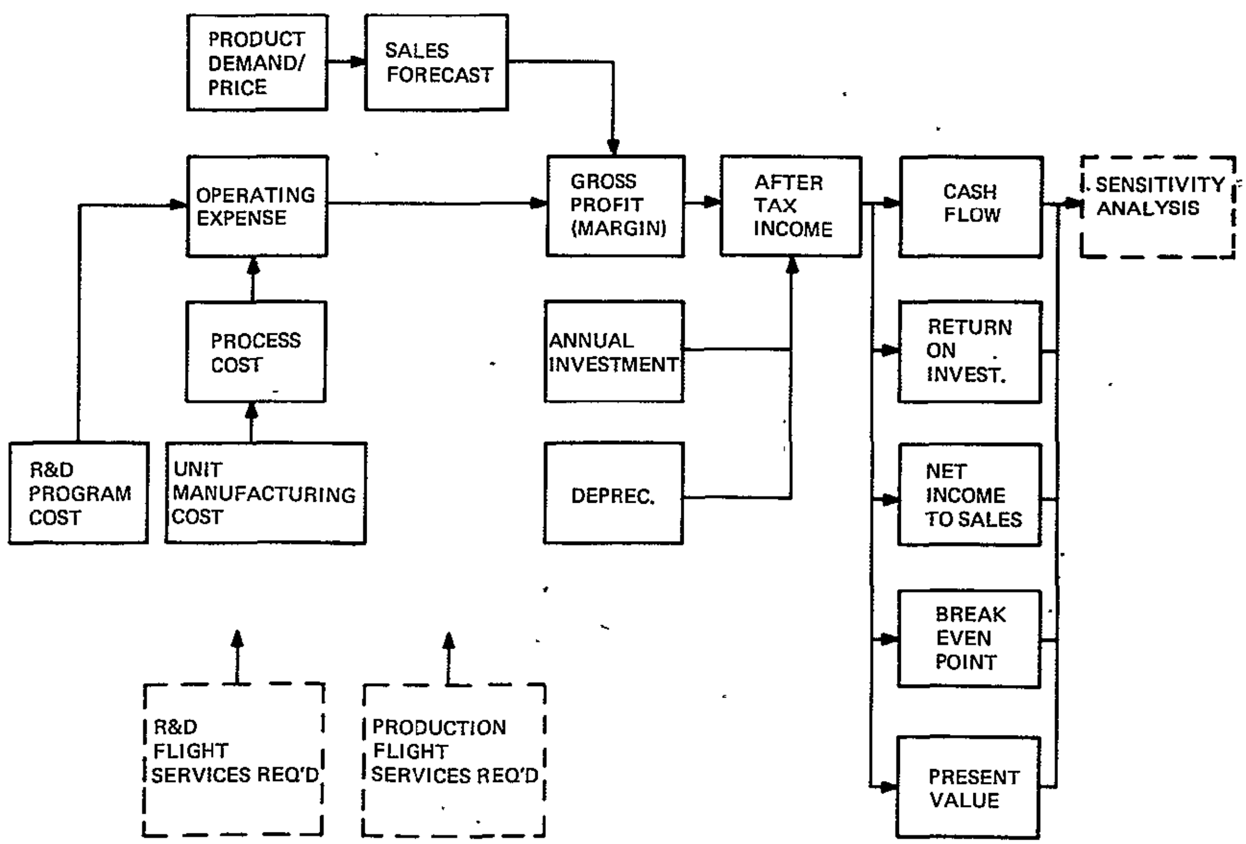


Figure 6. Summary of Business Planning Methodology (leading to Cash Flow)

used for calculating these items were chosen to roughly approximate the values for a "standard" business. Questionnaires were sent to the study contributors later in the study, to assess the validity of these factors as well as to establish the contributors overall reactions to the operating results which the financial forecast generated.

Assessment of Planning Method

The study method, within the time and knowledge constraints which existed, proved to be an effective means for creating a structure and baseline for the product concepts. Perhaps the most crucial aspect of the method, which is not apparent from the logic itself, was the process for establishing, via dialogue, a business framework which initially was quite strange to the study contributors. This process frequently required that hypothetical conditions or situations be created which the contributors could accept, reject, or modify based on experience and intuition. While advance planners in aerospace work are accustomed to dealing with new concepts and very long range forecasts, the commercial-oriented contributor typically confines his thinking to one or two year projections, based on equipment and processes which he knows quite well. The need to stretch the study contributor's thinking into periods 15 years in the future, and into space processes, space shuttle vehicles, space laboratories, etc. without confusion or loss of the contributor's confidence presented perhaps the greatest challenge in the study.

SECTION VI

EXAMPLE OF THROUGHPUT ANALYSIS LOGIC USED IN BENEFICIAL USES OF SPACE STUDY, PHASE III

The assessment of the economic feasibility of a conceptual product which would be produced in a conceptual facility and which would enter the commercial production phase in the distant future (e.g. 1985) presents many difficulties as to the creation of a usable data base in the face of so many unknowns. Iterative throughput analysis in conjunction with interviews of persons familiar with related ground process technology was used in the BUS Phase III Study to arrive at conceptual baseline data from which product and process costs, equipment configurations and weights, cost sensitivity, and critical development items could be extrapolated.

The attached lists of throughput elements and logic charts depict an early version of the throughput analysis as developed for the Surface Acoustic Wave Device (10-30 GHz) product candidate (one of four products addressed in the BUS-Phase III Study.) The analysis encompasses 6 process steps, 4 of which, at the time of the analyses, were to be conducted in orbit (Shuttle transport):

A - Crystal Growing (space)
  Crystal Cut & Polish (ground)

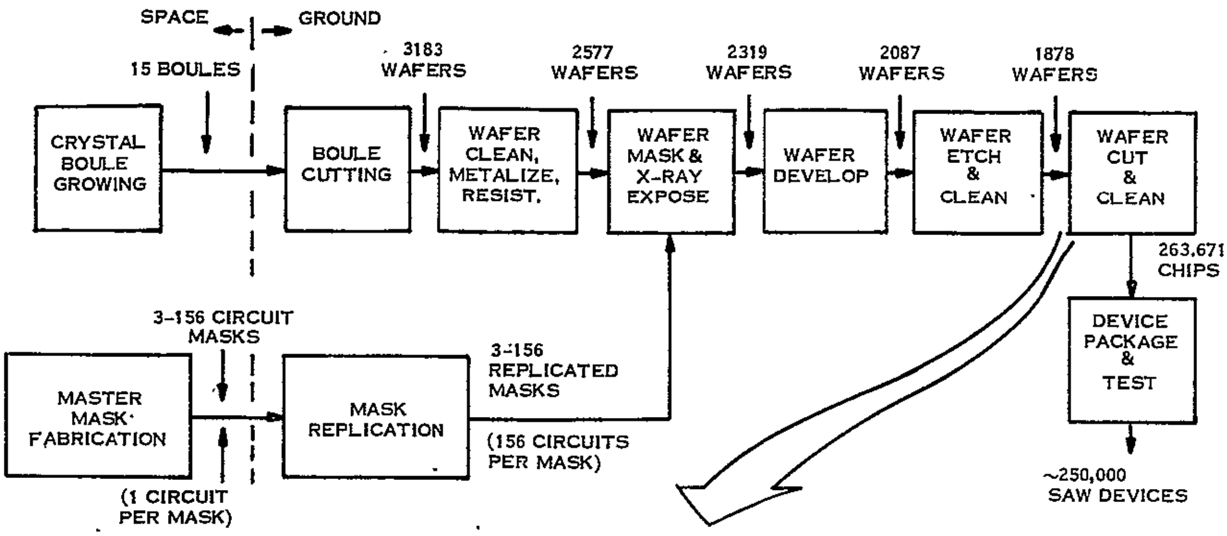
B - Crystal Clean, Metalize, Resist (space)

C - Mask & X-Ray Expose (space)

D - SAW Device Finishing (ground)

E - Mask Fabrication (space)

Steps B and C were subsequently changed to ground processes, so that the process became as pictured in Figure 1.



WAFER CUT AND CLEAN

NO. OF WAFERS INPUT PER YEAR	1878
YIELD FACTOR	90%
NO. OF CHIPS PER WAFER (AFTER CUTTING)	156 (MAY INCREASE WITH THINNER SAW)
NO. OF SAW CUTS PER WAFER (GANG SAW)	2 (1 X-AXIS, 1 Y-AXIS)
SAW CUTTING RATE	0.5 CM PER MINUTE
CUTTING DISTANCE PER WAFER (4 CM X 2)	8 CM
CUTTING TIME PER WAFER (8 CM ÷ 0.5 CM/MIN.)	16 MINUTES
NO. OF BLADES IN SAW	15
WAFERS CUT PER DAY (REQUIRED)(1603 ÷ 250 DAYS)	7 PER DAY
NO. OF WAFERS PER SAW PER DAY (CAPACITY) (480 MIN/DAY ÷ 16 MIN)	30
NO. OF SAWS REQUIRED (7 WAFERS REQ'D, 30 WAFERS PER DAY CAPACITY)	1
PERCENT OPERATOR ATTENTION	1 MAN PER SAW, 100%
NO. OF CHIPS OUTPUT PER YEAR (1878 X 156 X 90%)	263,671

Figure 1. Sample Throughput Analysis Summary

Books 1, 2, 3, and 4 of this Volume contain the respective current throughput analyses for each of the products under study.

Diagramming of the logic as shown in the charts is not essential to the analysis, but is useful as a means of validating the logic or presenting the throughput analysis and assumptions for assessment by others.

The following sequence of events comprise a throughput analysis for a typical early version of the production of Surface Acoustic Wave Components. This sequence is summarized in Figure 2, and the detailed flow pictured in Figures 3, 4, 5, and 6.

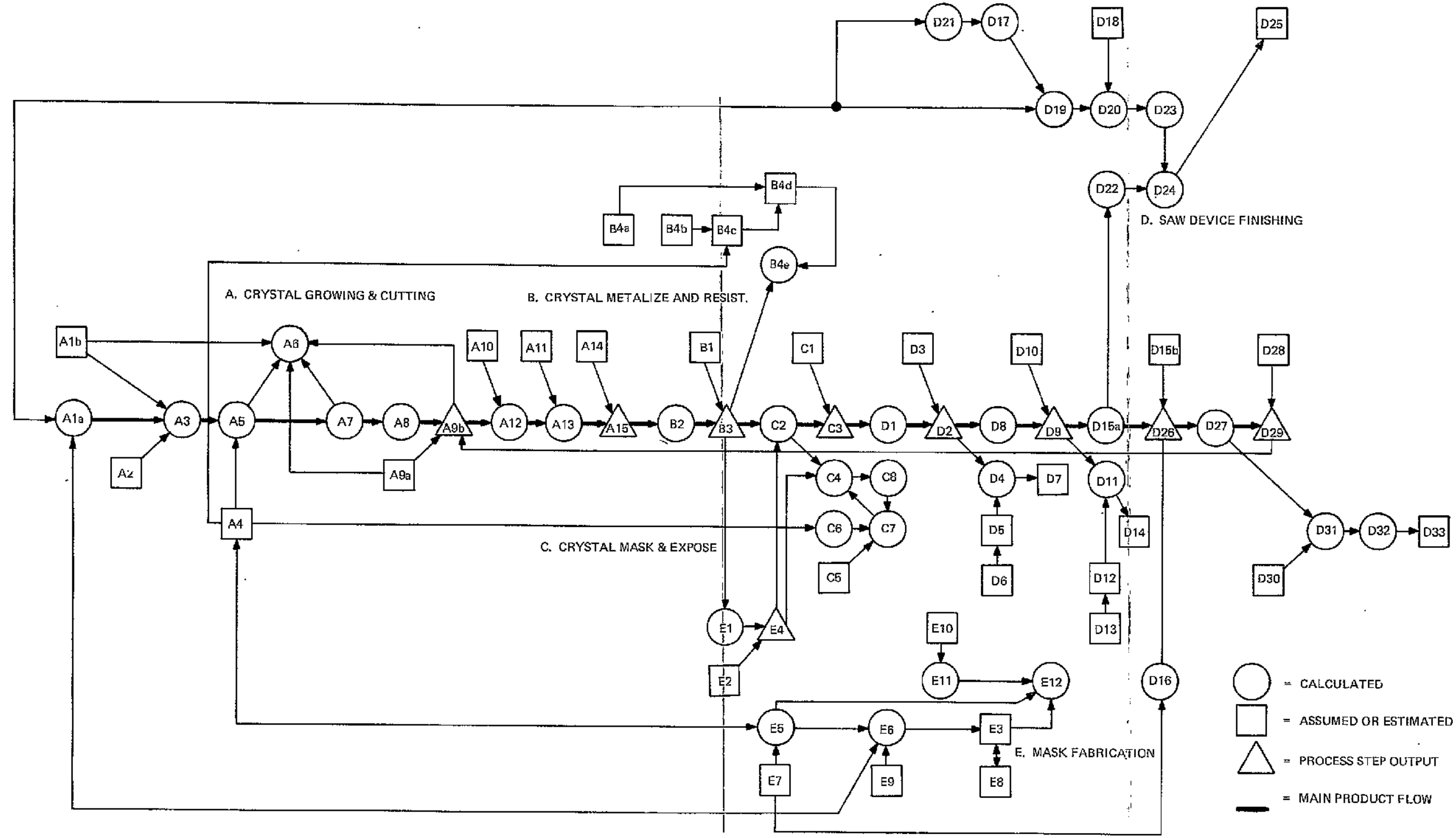


Figure 2. Surface Acoustic Wave (SAW) Device Throughput Analysis Logic Diagram (Summary)

SURFACE ACOUSTIC WAVE DEVICE
THROUGHPUT ANALYSIS

Network Event No.	
A.	**Crystal Growing/Cutting Process**
	Boule growing (space):
1	Boule
	(a) diameter 4 cm
	(b) length 22 cm
2	Pulling rate 0.5 cm/hr
3	Boule Pulling time 22 cm ÷ 0.5 cm/hr = 44 hrs
4	Flight time 156 hrs (7 day mission)
5	Boules per station per flight (156 ÷ 44) = 3.5 = 3 (allowing for handling, etc.)
6	No. of stations per flight 6
7	Boules per flight (6 stations x 3 boules/station) 18
8	Boule - centimeters/flt (18 x 22) = 396 cm
9	Boule - centimeter/yr
	(a) 396 cm x 10 flights/yr
	(b) 3960 cm/yr
	Boule cutting (ground)
10	Cutting waste factor 50%
11	Wafer thickness 1 mm (3-4 cm diameter)
12	Useful Boule centimeters after cutting (3960 cm x 50%) = 1980 cm
13	No. of 1 mm wafers after cutting (1980 cm ÷ 1 mm) = 19,800
14	Wafer reject factor (inspection) 60% (40% yield)
15	No. of 1 mm wafers after inspection (19,800 x 40%) = 7920

B. Crystal Clean, Metalize, Resist Process (space)

1	Yield factor	90%	
2	No. of wafers input/yr	7920	
3	No. of wafers output/yr	(7920 x 90%)	7130

4
- (a) Wafers per batch = 9;
- (b) Batches per hr = 1;
- (c) Batches per flight = 156
(156 hrs ÷ 1 batch/hr)
- (d) Wafers per flt
(156 batches x 9 = 1404)
- (e) No. of flts = 6
(7130 ÷ 156 x 9)
(7130 ÷ 1404)

C. Mask and X-Ray Expose Process (space)

1	Yield factor (after inspection)	80%	
2	No. of wafers input/yr	7130	
3	No. of wafers output/yr	(7130 x 80%)	5700 (after inspection)
4	No. of flights/yr (7130 ÷ 936 wafers/flt)		8
5	Wafers mask/exposure rate (1 station)		6 per hr
6	Hours per flt		156
7	Wafers output per flt (156 x 6)		936
8	No. of stations per flt		1

D. SAW Device Finishing Process (ground)

Developing

1	No. of wafers input/yr	5700
2	No. of wafers output/yr	5700
3	Yield factor	100%
4	No. of operating positions	1
5	Output rate	up to 100 wafers/day
6	Output rate	up to 12-15 wafers/hr
7	Percent operator attention	1 man, 25%

D. SAW Device Finishing Process (ground) (Cont'd)

Etch and Clean

8	No. of wafers input/yr	5700
9	No. of wafers output/yr	5700
10	Yield factor	100%
11	No. of operating positions	1
12	Output rate	up to 100 wafers/day
13	Output rate	up to 12-15 wafers/hr
14	Percent operator attention	1 man, 50%

Wafer Cut and Clean

15 No. of wafers input/yr

(a) 5700

(b) yield factor 100%

16	No. of chips per wafer (after cutting	156	
17	No. of saw cuts per wafer (gang saw)	2 (1 - x axis, 1 - y axis)	
18	Saw cutting rate	0.5 cm/minute	
19	Cutting distance per wafer (4 cm x 2)	8 cm	
20	Cutting time per wafer (8 cm ÷ 0.5 cm/min)		16 minutes
21	No. of blades in saw		15
22	Wafers cut per day (5700 ÷ 250 days)		23/day

23 No. of wafers per saw per day (480 min/day ÷ 16 min./wafer) = 30 capacity

24 No. of saws (23 wafers/day ÷ 30 wafers/saw) = 1 saw

25	Percent operator attention	1 man per saw, 100%
26	No. of chips output (5700 x 156)	889,200

Package and Test

27	No. of chips input (5700 x 156)	889,200
28	Yield factor	80%
29	No. of SAW devices output/yr (889,200 x 80%)	711,360

Package and Test (Cont'd)

30	Package and test rate per operation	20 devices/hr
31	Operator hrs/yr (889,200 ÷ 20/hr)	44,260
32	No. of operators required (44,260 ÷ 2000 hrs/oper)	23
33	No. of work stations (1 per operator)	23

E. Mask Fabrication (space)

1	No. of maskings required per yr (7130 wafers)	7130
2	Mask cycles per mask	1000
3	No. of mask stations (mask cutting)	1
4	No. of inspected masks required per yr (7130 ÷ 1000)	8
5	Cutting time per mask (resist exposure)	156 hrs
6	Mask diameter	3-4 cm
7	No. of circuits per mask	156 (100-200)
8	Electron beam (cutting) beamwidth	4-5 cm
9	Mask thickness	1 mm
10	Mask yield factor	80% (use 40-80% range)
11.	No. of masks required to be fabricated (8 req'd÷0.8 yield)	10
12	No. of shuttle flights (1 mask per flight)	10

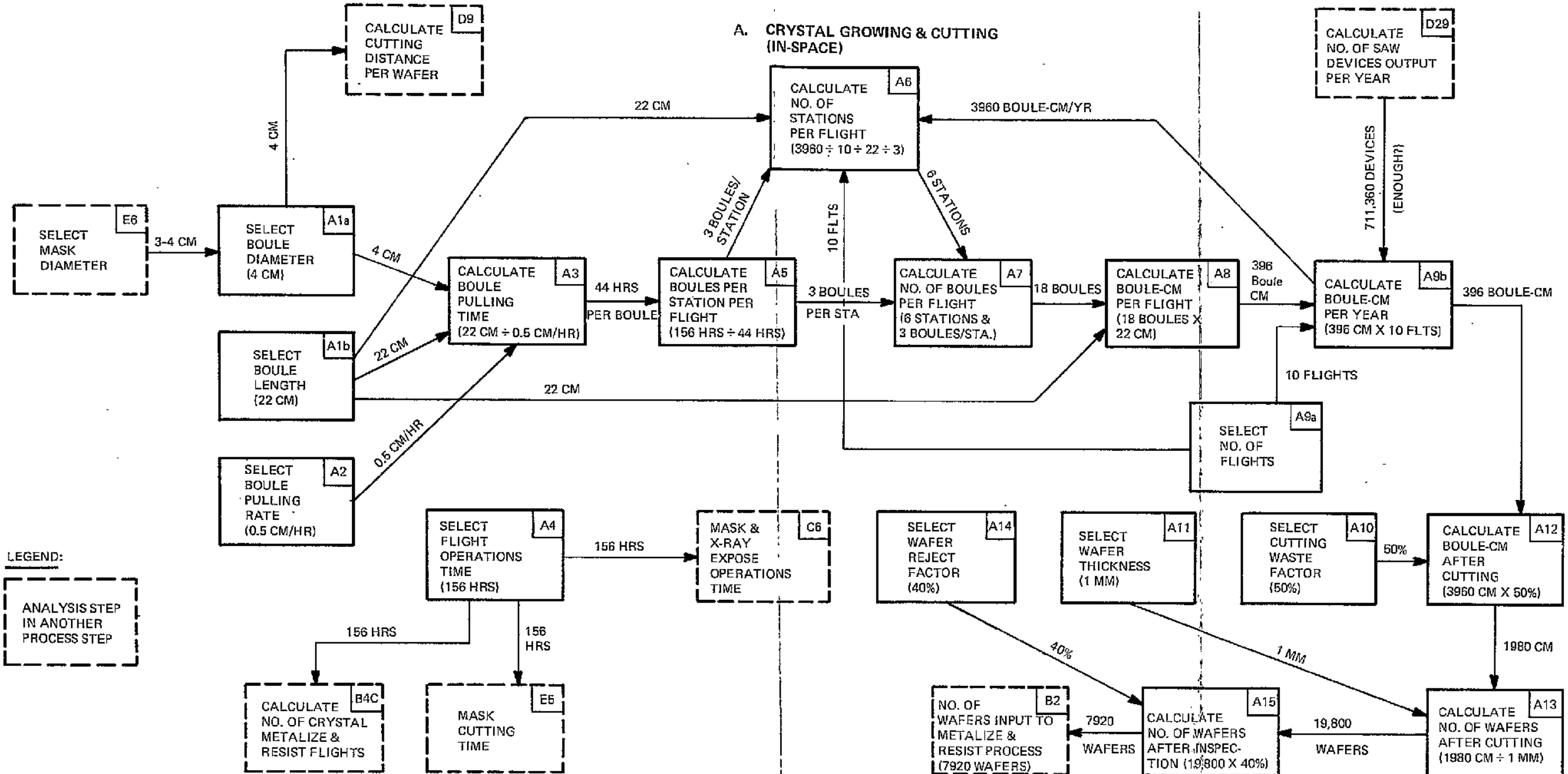


Figure 3. Throughput Analysis Logic for Crystal Growing and Cutting Process Step (Part of Saw Devices Process)

FOLDOUT FRAME 1

FOLDOUT FRAME 2

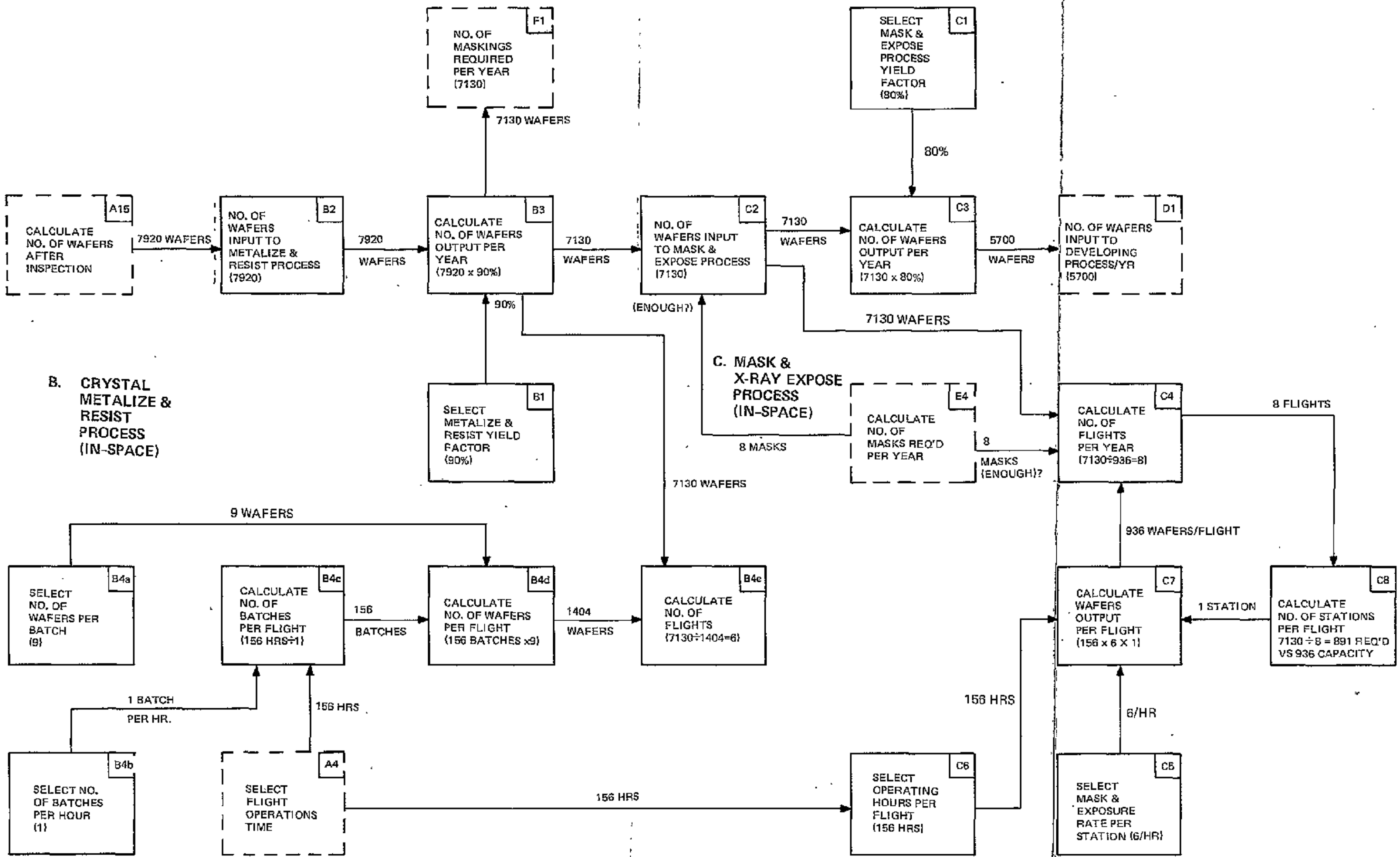


Figure 4. Throughput Analysis Logic for Crystal Wafer Metalize, Resist, and Mask/X-Ray Expose Processes (Part of SAW Devices Process)

FOLDOUT FRAME 1

FOLDOUT FRAME 2

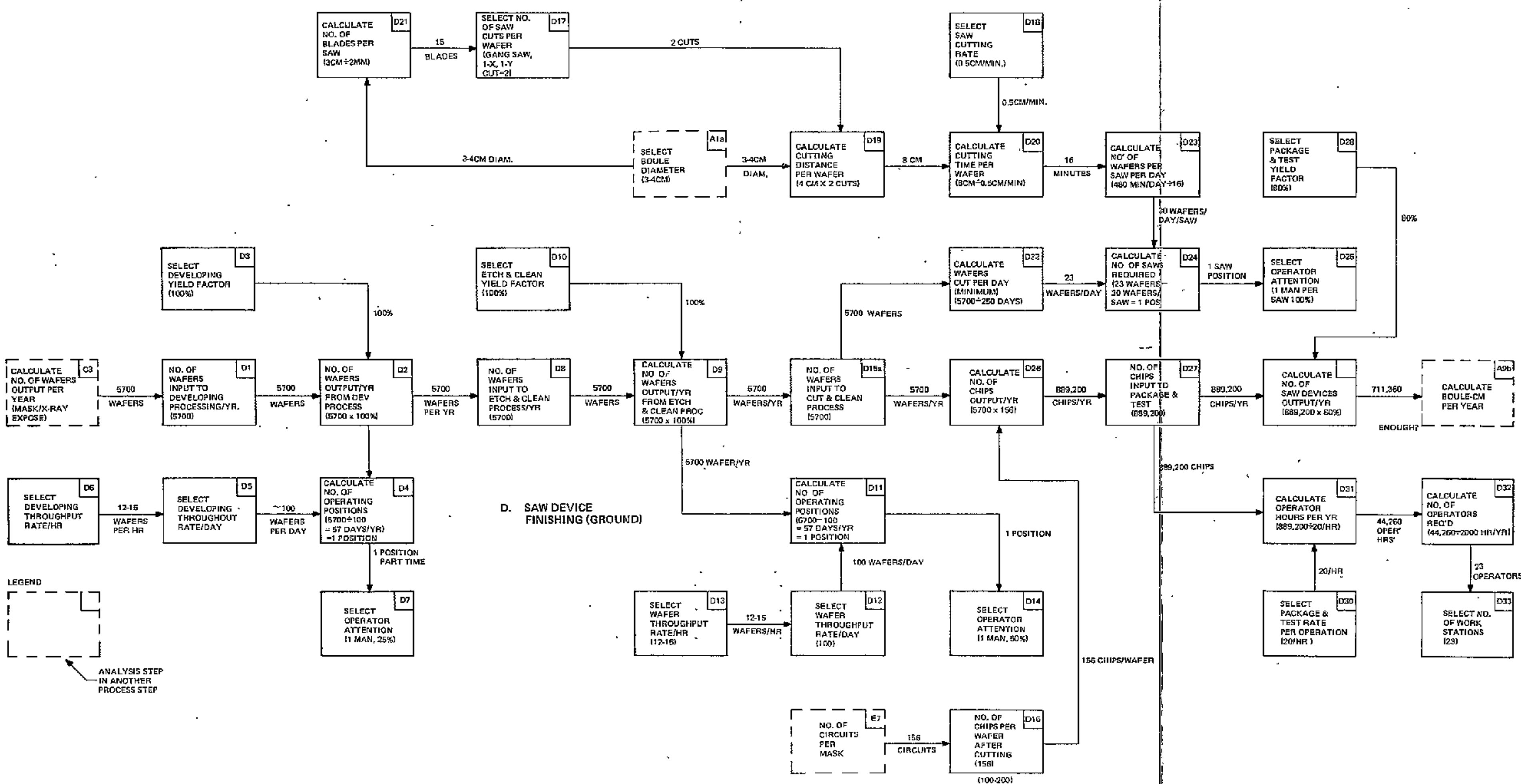


Figure 5. Throughput Analysis Logic for SAW Device Finishing Process (Part of SAW Device Process)

FOLDOUT FRAME 1

FOLDOUT FRAME 2

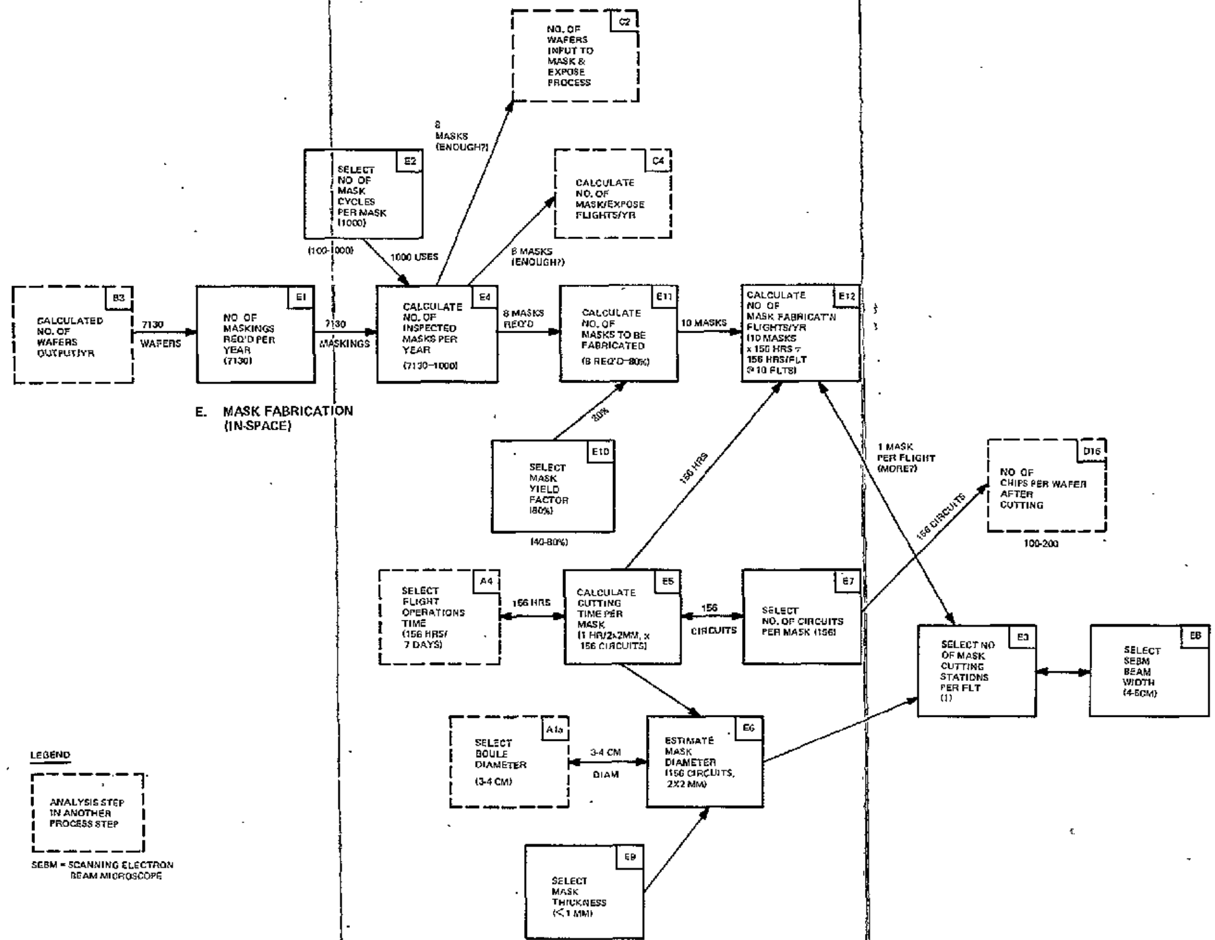


Figure 6. Throughput Analysis Logic for SAW Mask Fabrication (Part of SAW Device Process)

SECTION VII
SPACE PRODUCT MARKET ANALYSIS

VII-1. INTRODUCTION

One of the outputs of the Beneficial Uses of Space - Phase II Study is to be a market analysis which will provide the first intelligent "guesstimates" of the marketplace for each product under study.

Both NASA and GE recognize the difficulty of projecting to the distant future these nebulous product opportunities. What is needed therefore, is your best guess at this time for a number of key parameters, using whatever information or judgement which you can apply in the time available. The rationale for such information or judgement must be recorded. Be frank about how you arrived at your figures. For example, if you want to project product demands at the same level every year because you have no basis for having the demand rise or fall, do it that way and say so. And remember that your rough guesses are probably as good as anyone can do today.

Try to assess the market in terms of simply-defined versions of your space product, in order to avoid getting into too fine-grained details. For example, Tungsten x-ray targets, iso-enzymes, etc. If there is a particular advantage in distinguishing between one product and another (e.g., isoenzyme A and isoenzyme B), identify them as products A, B, etc. and use columns A, B, etc. in the accompanying format for showing the product demand, price, sales, etc.

VII-2. MARKET ANALYSIS

We have prepared a simple format for the required market analysis. It will address the following items:

1. Space Product Description (include your rationale)
2. Space Product Benefit & Advantages

3. Space Product Competitors and Alternatives (explain impact)
4. Space Product Purchaser and Application
5. Secondary Product Purchaser and Application
6. Space Product Life Cycle (include thought process)
7. Space Product Demand (Market) by year (include your rationale)
8. Space Product Price by year (include thought process)
9. Space Product Sales (Market Share) by year (include thought process)
10. Space Product Waste & Salvage

The attached work sheets are intended to simplify your entry of the basic information required. Where you are asked for your rationale or other explanatory comments, you may find it more convenient to document these on separate sheets which can be attached to the work sheets.

In this portion of the Study, the term Space Product refers to the product as it is received from the space facility (e.g., a sphere of tungsten, a gel specimen of isoenzyme, a sphere of transparent oxide glass, etc.) A Secondary Product is any item or items manufactured from the Space Product, (e.g., an x-ray tube target made from a sphere of space-processed tungsten).

The emphasis in this market analysis should be on the demand for, and sales of the Space Product, since the business venture assessment is focussed on the development of a space process and space facility to produce that product. However, an examination of secondary products will usually be necessary to guess the Space Product demand and its unit value (price) in the marketplace.

The Space Product Characteristics should be chosen to allow for space product uses in various secondary products (e.g., the tungsten sphere must be large enough to allow making at least one x-ray tube target from it; the transparent oxide sphere must

be large enough to be able to cut useful optical shapes from it, etc.) Once you have arrived at a unit product (e.g., 1-kg sphere, or 4 cm. diameter sphere, or 1 millimeter of isoenzyme, etc.) be sure to use this unit for your other guesstimates of unit price, sale of units, etc. If space product waste is expected in making secondary product, explain what this waste might be (quantity, per cent of product weight) and what effect it might have on the unit price, re-use, etc.

The Space Product is inherently an expensive item on a unit weight basis. Therefore product applications should be sought which lead to the highest dollar per pound prices achievable while retaining a significant product demand.

SPACE PRODUCT MARKET ANALYSIS WORK SHEETS

Product Area ____

Estimated by ______________________________ Date ____________

1. Space Product Description

Physical Characteristics (unit dimensions, weight, features, chemistry)

Basis for Product Characteristics

2. End Use Benefits & Advantages

Advantage	Benefit to Whom	Type Benefit (place x in applicable column): Economic	Social	Direct	Indirect

3. Space Product Competitors/Alternatives

Competing or Alternate Product	Competing Features/Date	Space Product Advantage

Impact of Competing products or alternatives (explain)

4. Space Product Purchaser/Application

(Description of customers who will buy the product and initial use)

Purchaser	Application

5. Secondary Product Purchaser/Application

(Description of those who will purchase space products from Space Product Purchaser and intended use)

Purchaser	Application/Description

6. Product Life Cycle (duration of each phase)

	From (year)	To (year)
Introduction Phase		
Growth Phase		
Maturity Phase		
Decline Phase		
Exit Phase		

Basis for Life Cycle (give your rationale)

7. Space Product Demand (Total Market) (Units by year, 1980-1992) Unit__________

1980-	1986-
1981-	1987-
1982-	1988-
1983-	1989-
1984-	1990-
1985-	1991-
	1992-

Basis for Product Demand (give your rationale)

8. Space Product Price (price per unit by year, 1980-1992) Unit__________

1980-	1986-
1981-	1987-
1982-	1988-
1983-	1989-
1984-	1990-
1985-	1991-
	1992-

Basis for establishing price (give your rationale)

9. Space Product Sales (Market Share) (Units by year) Unit__________

1980-	1986-
1981-	1987-
1982-	1988-
1983-	1989-
1984-	1990-
1985-	1991-
	1992-

Basis for Market Share/Sales Estimate (explain)

10. Space Product Waste and Salvage (describe)

SECTION VIII

RECOMMENDED COST MODEL FOR SHUTTLE SERVICES IN THE R&D PHASES OF SPACE PROCESSING PAYLOAD PROGRAMS

Attached is a candidate cost model for determination of costs associated with the use of the Space Shuttle to carry out Space Processing payload experiments in orbit. This model was used to establish and incorporate user costs in assessments of business feasibility in the Beneficial Uses of Space Phase III Study (NAS 8-28179).

The memo is organized as follows:

1.0 Explanation of Cost Model

2.0 Calculation of User Payload Costs

3.0 Determination of User Rates

4.0 Recommendations for User Cost Rates

Attachments:

A. List of Cost Model Factors

B. Candidate Incentive and Policy Statement

C. Example of User Cost Determination

VIII.1. EXPLANATION OF COST MODEL

The purpose of the Model is to arrive at equitable allocation of Shuttle operating costs among payloads and to provide a basis for cost rates for Shuttle use. The objective is to recover all Shuttle/Spacelab operational costs. If costs are to be recovered on a per-mission basis, NASA may wish to consider the possibility of recovering more than mission costs in cases of high utilization, as a hedge against

other missions which might encounter low utilization. As a more attractive alternative, in an approach analogous to those utilized by commercial cargo transportation industries (truck, train, air transport), utilization rates and costs are proposed to be allocated on the basis of, say, an annual mission profile, which would tend to even out the charges to all users. Eliminating a high cost differential for high inclination/high altitude (thus, smaller payload capacity) missions will encourage a more even distribution of payloads (not sensitive to orbit) among missions, and tend to increase over-all utilization factors. Although not specifically addressed here, the principles of the Model may be applicable to payloads of other disciplines and Space Tug service, whereby users would pay their fair share of services on a weight, volume, etc. basis. A summary of the Cost Model and list of cost factors are given in Attachments A and B. A list of policy statements relative to the Model is given in Attachment C.

VIII.1.1 GENERAL EXPRESSION

The general expression of the Model is:

$$C_M = C_1 + C_2 + C_3 + C_4$$

C_M = Total per-mission cost of the shuttle operations, averaged over, say, a year.

C_1 = Portion of C_M allocated to up-transport phase

C_2 = Portion of C_M allocated to on-orbit phase

C_3 = Portion of C_M allocated to down-transport phase

C_4 = Portion of C_M allocated to Ground Operations

No distinction is made in the Model between research missions and missions for development of commercial applications. Annual Shuttle operations costs consist of direct costs of the mission plus allocated costs such as the shared cost of

orbiter vehicle life, (depreciation) shared cost of booster life, etc. Allocations of operations costs (C_M) to mission phase cost (C_1, C_2, C_3, C_4) is a device commonly used by cargo carriers for encouraging traffic during selected times while discouraging others. On that basis, weighted allocations are recommended which will recover more of the mission costs in one phase than in another. For initial analysis, we recommend the following phase weighting:

Up-Transport	$C_1 = 45\%$ of C_M
On-Orbit	$C_2 = 22.5\%$ of C_M
Down-Transport	$C_3 = 22.5\%$ of C_M
Ground Operations	$C_4 = 10\%$ of C_M

The split is recommended for the purposes of 1) Recovering a portion of costs from all payloads, including those left in orbit, or launched on non-retrieval missions, and 2) discouraging the down transport of payloads, since the weight and center-of-gravity limitations on return capacity are more stringent than on the up-transport capacity. Users will thus trade off the value of retrieving their payloads versus the cost of recovery. Such an approach is in consonance with low-cost guidelines, and is an aid in optimizing payloads. The allocation of costs to the on-orbit phase provides a means of charging users who utilize STS resources while on-orbit.

Further reallocation of the costs allocated to mission phases is made on the basis of the major resources utilized by payloads during each mission phase. For purposes of this analysis, such resources include at appropriate phases, payload bay weight and volume, on-orbit power and crew time, pre and post-flight mechanical and electronic ground support, etc. This approach, too, is analogous to commercial cargo transportation industry practices, where refrigerated carriers are more costly

than non-refrigerated; oversized cargos, though light weight, pay higher rates than normal; etc.

VIII.1.2 COST ALLOCATION AND RATES FOR THE UP-TRANSPORT MISSION PHASE

The cost expression for the up-transport phase is:

$$C_1 = C_{11} + C_{12}$$

where

C_{11} = Portion of C_1, allocated to up-transport volume

C_{12} = Portion of C_1, allocated to up-transport weight

The allocation of C_1 to C_{11} and C_{12} is based on the relative emphasis to be given to Volume and Weight in mission planning. Present studies indicate that volume will more often be a limiting factor than weight. An allocation is recommended which applies a dis-incentive to volume:

Volume C_{11} = 60% of C_1

Weight C_{12} = 40% of C_1

Total + 100% of C_1

C_{11} and C_{12} are further allocated as follows:

$$C_{11} = (V_{11} \cdot U_{11} \cdot R_{11})$$

where

V_{11} = Payload Bay volume capacity (300 cubic meters)

U_{11} = Utilization factor for up-transport volume

(The fraction of the total payload bay volume occupied by payload, Total volume would be averaged on a yearly basis in order to even out the variations in usable volume due to fluctuation in available payloads and variations in orbit selection. This "evening-out" is necessary in order to make all flights equally acceptable to payloads which are indifferent to orbit selection. Otherwise, such payloads would tend toward the low altitude, 28.5° inclination orbits, which accommodate larger weights, thus possibly larger volumes of payloads. With U_{11} as an average yearly utilization, some individual flights will be under-utilized, others over-utilized, but over the year all costs will be accounted for.)

R_{11} = Cost rate for up-transport volume (dollars per cubic meter). (This rate rate is such that the utilized volume V_{11} time the utilization factor U_{11} yields the average cost C_{11}.

Also, $C_{12} = (W_{12} \cdot U_{12} \cdot R_{12})$

where

W_{12} = Payload by weight capacity for up-transport (29,500 kilograms)

U_{12} = Utilization factor for up-transport weight (percentage). (As noted above for U_{11}, this factor should be averaged on a yearly basis to even out payload and orbit variations.)

U_{12} = Cost rate for up-transport weight (dollars per kilogram)

Given C_{11} and C_{12} by virtue of allocation from C_1, and given V_{11} and W_{12}, the utilization factors and rate factors can be addressed.

In practice, it is expected that utilization factors will at first be derived analytically, and later be derived from operating experience. For the time being we recommend:

U_{11} = 70% (Volume)

U_{12} = 60% (Weight)

The rate factors (R_{11} and R_{12}) can then be determined as follows:

$$R_{11} = \frac{C_{11}}{V_{11} \cdot U_{11}} = \frac{C_{11}}{300\ M^3\ (0.7)} = \$.004762\ C_{11} \text{ per cubic meter}$$

$$R_{12} = \frac{C_{12}}{(W_{12} \cdot U_{12})} = \frac{C_{12}}{29,500\ \text{kg}\ (0.6)} = \$0.0000565\ C_{12} \text{ per kilogram}$$

The above methods for estimating utilization factors and cost rates are analogous to current cargo transportation rate estimating methods, wherein such factors do not vary from trip to trip but rather, are established beforehand, carried through a given period, and then adjusted for a later period if experience so dictates.

VIII.1.3 COST ALLOCATION AND RATES FOR ON-ORBIT MISSION PHASE

The Cost expression for the on-orbit phase is:

$$C_2 = C_{21} + C_{22} + C_{23} + C_{24}$$

where, based on estimates of the most limiting on-orbit resources.

C_{21} = Portion of C_2 allocated to on-orbit Energy use.

C_{22} = Portion of C_2 allocated to on-orbit Crew support use.

C_{23} = Portion of C_2 allocated to on-orbit Data transmission service use.

C_{24} = Portion of C_2 allocated to on-orbit Data Processing service use.

The allocations of C_2 to C_{21}, C_{22}, C_{23}, and C_{24} is based on dis-incentivizing each area of resource. A typical recommended allocation among these resources is:

$$
\begin{aligned}
C_{24} &= \;\; 45\% \text{ of } C_2 \\
C_{22} &= \;\; 45\% \text{ of } C_2 \\
C_{23} &= \;\;\;\; 5\% \text{ of } C_2 \\
C_{24} &= \;\; \underline{\;\;5\% \text{ of } C_2} \\
& \;\;\;\; 100\% \text{ of } C_2
\end{aligned}
$$

No separate cost is set for thermal dissipation since energy use reflects the concomitant requirement for cooling. In the event that other than on-board electrical power is used (e.g. solar concentrator), provision will have to be made for a cost for thermal dissipation.

C_{21}, C_{22}, C_{23}, and C_{24} are further allocated as follows:

$$C_{21} = (E_{21} \cdot U_{21} \cdot R_{21})$$

where

E_{21} = Average on-orbit energy capacity in KWH available for payloads per mission (700 KWH, nominally). (This capacity must include any auxiliary power systems or kits added to supplement the basic power supply). The range of available basic energy supply is presently 400 to 700 KWH. Additional energy is available in increments of 840 KWH, up to 4 increments.

U_{21} = Utilization factor for on-orbit energy (percentage). (As discussed earlier, this should be estimated on a yearly basis.)

R_{21} = Cost rate for on-orbit energy consumption (dollars per kilowatt hour).

and

$$C_{22} = (S_{22} \cdot U_{22} \cdot R_{22})$$

where

S_{22} = Crew payload support, on-orbit (336 man hours)
Available crew support is taken as 2 men, 24 hours per day, 7 days = 336 man hours.

U_{22} = Utilization factor for crew support (percentage)

R_{22} = Cost rate for on-orbit crew usage (dollars per man hour)

and

$$C_{23} = (T_{23} \cdot U_{23} \cdot R_{23})$$

where

T_{23} = Factor representing total (video, analog, digital) space to ground transmission capacity, in terms of RF bandwidth. Digital data rates are equated to RF bandwidth on the basis 1 KBPS = 1 KHz of bandwidth. On this basis an available capacity of 6 MHz BW for TV and analog information plus 50 MBPS of digital information gives 6 + 50 = 56 MHz of RF bandwidth available.

U_{23} = Utilization factor for data transmission, averaged per mission and averaged over a year.

R_{23} = Cost rate for on-orbit data transmission (dollars per MHz of RF bandwidth).

and

$$C_{24} = (P_{24} \cdot U_{24} \cdot R_{24})$$

where

P_{24} = Factor representing total mass memory capacity of the on-board experiment computer = 64K words.

U_{24} = Utilization factor for data processing (word storage), averaged per mission and over a year.

R_{24} = Cost rate for on-orbit data processing usage (dollars per word).

Given the allocations C_{21}, C_{22}, C_{23} C_{24} by allocation from C_2, and given the basis for factors E_{21}, S_{22}, T_{23} and P_{24}, the utilization factors and rates can be addressed. For initial estimates, the following utilization factors are recommended.

U_{21} = 90% (Energy)

U_{22} = 50% (Crew)

U_{23} = 50% (Data Transmission)

U_{24} = 80% (Data Processing)

The rate factors can then be determined as follows:

(Energy) $$R_{21} = \frac{C_{21}}{E_{21} \cdot U_{21}} = \frac{C_{21}}{700 \text{ KWH } (0.9)} = \$.0015873C_{21}$$ per KWH

(Crew) R $$R_{22} = \frac{C_{22}}{S_{22} \cdot U_{22}} = \frac{C_{21}}{336 \text{ MH } (0.5)} = \$.0059524C_{22}$$ per man hour

(data Trans.)

$$R_{23} = \frac{C_{23}}{T_{23} \cdot U_{23}} = \frac{C_{23}}{56 \text{ MHz } (0.5)} = \$.035714\ C_{23}$$

per MHz of RF bandwidth

(Data Proc.)

$$R_{24} = \frac{C_{24}}{P_{24} \cdot U_{24}} = \frac{C_{24}}{64\text{K words } (0.8)} = \$.019531 C_{24}$$

per kiloword

No cost factors have been included to provide for interference with other users, abort of mission, damage to shuttle equipment, etc. Also, no factor has been included to recognize the differences in experiment operating durations in orbit. It is felt that mission duration will be a primary factor in assigning compatible payloads, so that differences in operating times should be small, and such differences will be accounted for in energy usage, crew time utilization, etc. While not recommended here, each of these factors can be addressed on a case-by-case basis, or they can be introduced into the general cost model if desired. The incentive and dis-incentive aspects of costs must be considered in all costing factors. For example, introducing a cost allocation for length of operating time in orbit will probably act to discourage longer orbital operating times.

VIII.1.4 COST ALLOCATION AND RATE FOR DOWN-TRANSPORT PHASE

The cost expression for the Down-Transport phase is:

$$C_3 = C_{31}$$

where

C_{31} = Portion of C_3 allocated to Down-Transport Weight capacity (in this case, 100% of C_3)

All of the costs associated with C_3 are presently assigned to cost recovery on the basis of payload weight.

C_{31} is further allocated as follows:

$$C_{31} = (W_{31} \cdot U_{31} \cdot R_{31})$$

where

W_{31} = Weight capacity for Down-Transport (kilograms)

U_{31} = Utilization factor for Down-Transport weight (percentage)

R_{31} = Cost rate for Down-Transport weight (dollars per kilogram)

Given C_{31} as identical to C_3, and given W_{31} (maximum down-transport payload weight of shuttle vehicle, e.g. 14,500 kilograms), the uitlization factor (U_{31}) and rate factor (R_{31}) can be addressed. The utilization factor is determined in terms of the expected weight utilization on a given return mission, or in terms of expected average utilization over a number of missions. A recommended utilization factor is 90%.

The rate factor (R_{31}) can then be determined as follows:

$$R_{31} = \frac{C_{31}}{(W_{31} \cdot U_{31})}, \quad \text{(Cost rate for weight returned)} = \frac{C_{31}}{14{,}500 \text{ kg } (0.9)} = \$\,.00007663C_{31} \text{ per kg.}$$

VIII.1.5 COST ALLOCATION AND RATE FOR GROUND OPERATIONS

The Cost expression for Ground Operation is:

$$C_4 = C_{41} + C_{42}$$

where

C_{41} = Portion of C_4 allocated to ground mechanical handling operations on the basis of payload volume (V_{11}) - a simplifying assumption which relates mechanical handling to payload volume.

C_{42} = Portion of C_4 allocated to ground electronic handling operations on the basis of payload Data Processing, where electronic operations are assumed to be related to payload data processing requirements (P_{24})

The allocation of C_4 to C_{41} and C_{42} is suggested as follows:

C_{41} = 25% of C_4

C_{42} = 75% of C_4

Total = 100%

C_{41} and C_{42} are further allocated as follows:

$$C_{41} = V_{11} \cdot U_{41} \cdot R_{41}$$

where

V_{11} = Payload bay volume capacity (300 cubic meters)

U_{41} = Utilization factor for mechanical handling ground operations based on payload volume.

R_{41} = Cost rate for mechanical handling ground operations based on payload volume. (dollars per dubic meter).

$$C_{42} = P_{24} \cdot U_{42} \cdot R_{42}$$

where

P_{24} = On-orbit data processing (word storage) capacity = 64K words

U_{42} = Utilization factor for electronics handling operations based on payload data processing.

R_{42} = Cost rate for electronics handling operations based on payload data processing (dollars per word of on-board data storage).

Given C_{41} and C_{42} by allocation from C_4, and given V_{11} and P_{24} from previous calculations, the utilization and rate factors can be addressed. Utilization factors are suggested as follows:

U_{41} = 70%

U_{42} = 60%

The rates can then be established as follows:

$$R_{41} = \frac{C_{41}}{V_{11} \cdot U_{41}} = \frac{C_{41}}{300 \cdot (0.7)} = \$.004762 C_{41} \text{ per cubic meter}$$

$$R_{42} = \frac{C_{42}}{P_{24} \cdot U_{42}} = \frac{C_{42}}{64K\,(0.6)} = \$.000026 C_{42} \text{ per word}$$

VIII. 2. CALCULATION OF USER PAYLOAD COSTS

The user is given the Cost rates as established above. He can then estimate his costs for space shuttle services as follows by inserting his values for all factors shown with a prime mark:

a) Up-transport volume Costs $= C''_{11} = (V'_{11} \cdot R_{11})$

b) Up-transport weight costs $= C''_{12} = (W'_{12} \cdot R_{12})$

c) On-orbit energy costs $= C''_{21} = (E'_{21} \cdot R_{21})$

d) On-orbit crew costs $= C''_{22} = (S'_{22} \cdot R_{22})$

e) On-orbit data trans. costs $= C''_{23} = (T'_{23} \cdot R_{23})$

f) On-orbit data proc. costs $= C''_{24} = (P'_{24} \cdot R_{24})$

g) Down-transport weight costs $= C''_{31} = (W'_{31} \cdot R_{31})$

h) Groun Ops. mechanical handling costs $= C''_{41} = (V'_{11} \cdot R_{41})$

j) Ground Ops electronics handling $= C''_{42} = (P'_{24} \cdot R_{42})$

j) Total costs $= C''_M = C''_{11} + C''_{12} + C''_{21} + C''_{22} + C''_{23} + C''_{24}$

$+ C''_{31} + C''_{41} + C''_{42}$

VIII.3. DETERMINATION OF USER COST FROM COST MODEL

1. Model

$C_M = C_1 + C_2 = C_3 + C_4$

C_M = total per mission cost of shuttle operations, averaged

C_1 = portion of total cost allocated to up-transport phase

C_2 = portion of total cost allocated to on-orbit phase

C_3 = portion of total cost allocated to down-transport phase

C_4 = portion of total cost allocated to Ground Operations

2. Phase Weighting

	Based on \$10.7M Mission
$C_1 = 45\%$ of C_M	\$4815K
$C_2 = 22.5\%$ of C_M	2408K
$C_3 = 22.5\%$ of C_M	2407K
$C_4 = 10\%$ of C_M	1070K
TOTAL 100% of C_M	\$10700K

3. Up-Transport Mission Phase:

$C_1 = C_{11} + C_{12}$ $\quad$ C_{11} = alloc. to volume (\$2889K)

100 = (60%) + (40%) $\quad$ C_{12} = alloc. to weight (\$1926K)

4815K = 2889K + 1926K $\quad$ C_{12} = alloc. to weight (\$1926K)

$C_{11} = (V_{11} \cdot U_{11} R_{11})$

V_{11} = Payload bay volume capacity (M^3) = $300M^3$

U_{11} = Utilization factor = 0.7

R_{11} = Rate (dollars per cubic meter) = 2889K - (300x0.7)
= 2889K - 210 = \$ 13,760/M^3

3. Up Transport Mission Phase (Cont'd)

$C_{12} = (W_{12} \cdot U_{12} \cdot R_{12})$

W_{12} = Payload bay weight capacity (kg) = 29,500 kg

U_{12} = Utilization factor = 0.6

R_{12} = Rate (dollars per kg) = 1926 - (29,500 x 0.6) =

1926 - 17700 = $108.81/kg

4. On-Orbit Mission Phase

$C_2 = C_{21} = C_{22} + C_{23} + C_{24}$

100% = (45%) + (45%) + (45%) + (5%)

2408K = 1084K + 1083K + 120K + 120K

C_{21} = Alloc. to Energy

C_{22} = Alloc. to Crew Time (Support)

C_{23} = Alloc. to Data Recording & Transmission

C_{24} = Alloc. to On-Orbit Data Processing

$C_{21} = (E_{21} \cdot U_{21} \cdot R_{21})$

E_{21} = Average on-orbit energy capacity (KWH) (700 KWH)

U_{21} = Util. factor = 0.9

R_{21} = Rate (dollars Per KWH) = 1084 - (700 x 0.9)

= 1084K - 630 = $1721/KWH

$C_{22} = (S_{22} \cdot U_{22} \cdot R_{22})$

S_{22} = Crew payload support capacity (man krs) = 336 man hrs

U_{22} = Util. factor = 0.5

R_{22} = Rate (dollars per man hr) = 1083K - (336 x 0.5)

= 1083K - 168 = $6446/man hr.

$C_{23} = (T_{23} \cdot U_{23} \cdot R_{23})$

T_{23} = Data Recording & Transmission Capacity (See Note 1) = 56 MHZ

U_{23} = Util. Factor = 0.5 (average per mission & per year)

R_{23} = Rate (dollars per MHz) = 120K - (0.5 x 56) = $4286/MHz of RF Bandwidth

$C_{24} = (P_{24} \cdot U_{24} \cdot R_{24})$

P_{24} = On-orbit Data Processing Capacity (See note 2) = 64K words

U_{24} = Util. factor = 0.8 (averaged per mission & per year)

R_{24} = Rate (dollars per word) = 120K - (0.8 x 64K)

= <u>$2.36/word of memory</u>

Note (1) T_{23} = factor representing total video, analog and digital data air/ground RF bandwidth transmission capacity (analog & Video Bandwidth, MHz) plus digital bit rate (MBPS) = 6 (MHz) + 50 (MBPS) = 6 MHz + 50 MHz = 56 MHz (conversion of digital data, 1 MBPS equals 1 MHz of RF Bandwidth).

Note (2) = P_{24} = factor representing capacity of dedicated experiments computer 64 K words of memory.

5. Down-Transport Phase

$C_3 = C_{31}$ C_{31} = Alloc. to Weight = $2407 K

$C_{31} = W_{31} \cdot U_{31} \, R_{31}$

W_{31} = weight capacity for down-transport = 14,500 kg

U_{31} = Utilization Factor = 0.9

R_{31} = Rate (dollars per kg) = \$2407K - (14,500 x 0.9)

= 2407K - 13050 = \$184.44/kg.

6. Ground Operations Phase

$C_4 = C_{41} + C_{42}$	C_{41} = Alloc. to mechanical handling = 268 K
100% = 25% + 75%	C_{42} = Alloc. to electronics handling = 802 K
	1070 K

$C_{41} = V_{11} \cdot U_{41} \cdot R_{41}$

V_{11} = Payload bay volume capacity = 300 cubic meters

U_{41} = Utilization factor = 0.7

R_{41} = Rate (dollars per M^3) = 268 K - (0.7 x 300)

= 268 K - 210 = \$1276/M^3

$C_{42} = P_{24} \cdot U_{42} \cdot R_{42}$

P_{24} = On-orbit data processing capacity = 64K words

U_{24} = Utilization factor = 0.6

R_{42} = Rate (dollars per word) = 802K - (64K x 0.6)

= 802K - 38.4K = \$20.89/word

VIII. 4. RECOMMENDED USER SPACE SHUTTLE UTILIZATION COST RATE

Rate Symbol	Factor	Experiment Payload Cost Rate
R_{11}	Up Transport Volume	\$13,760/cubic meter
R_{12}	Up Transport Weight	\$108.81/kg
R_{21}	On-Orbit Energy	\$1721/KWH
R_{22}	On-Orbit Crew	\$6446/Man Hr
R_{23}	On-Orbit Data Transmission	\$4286/MH_Z of RF Bandwidth
R_{24}	On-Orbit Data Processing	\$2.36/word of Exper. Computer Storage
R_{31}	Down Transport Weight	\$184.44/kg.
R_{41}	Ground Operations Mechanical Handling	\$1,276/cubic meter
R_{42}	Ground Operations Electronic Handling	\$20.89/word of Exp. Computer Storage

ATTACHMENT A

LIST OF COST MODEL FACTORS

(Add double prime notation to indicate user cost factors, e.g. C''_M, C''_1, etc.)

Factors

C_M = Total allocated cost of a shuttle mission

C_1 = Cost allocated to Up-transport phase

C_2 = Cost allocated to On-orbit phase

C_3 = Cost allocated to Down-transport phase

C_4 = Cost allocated to Ground operations

C_{11} = Cost allocated to up-transport volume

C_{12} = Cost allocated to Up-transport weight

C_{21} = Cost allocated to On-orbit energy

C_{22} = Cost allocated to On-orbit crew, support

C_{23} = Cost allocated to On-orbit data transmission

C_{24} = Cost allocated to On-orbit data processing

C_{31} = Cost allocated to Down-transport weight

C_{41} = Cost allocated to Ground mechanical handling operations considerations

C_{42} = Cost allocated to Ground electronic handling operations considerations

U_{11} = Utilization factor for Up-transport volume

U_{12} = Utilization factor for Up-transport weight

U_{21} = Utilization factor for On-orbit energy

ATTACHMENT A

LIST OF COST MODEL FACTORS (Cont'd)

U_{22} = Utilization factor for On-orbit crew support

U_{23} = Utilization factor for On-orbit data transmission

U_{24} = Utilization factor for On-orbit data processing

U_{31} = Utilization factor for Down Transport weight

U_{41} = Utilization factor for Ground mechanical handling operations (volume)

U_{42} = Utilization factor for Ground electronics handling operations

V_{11} = Volume capacity for up-transport

W_{12} = Weight capacity for up-transport

E_{21} = Energy capacity, on-orbit

S_{22} = Crew support capacity, on-orbit

T_{23} = Data transmission capacity, on-orbit

T_{24} = Data processing capacity, on-orbit

R_{11} = Cost rate for up-transport volume

R_{12} = Cost rate for up-transport weight

R_{21} = Cost rate for On-orbit energy

R_{22} = Cost rate for On-orbit crew support

R_{23} = Cost rate for On-orbit data transmission

R_{24} = Cost rate for On-orbit data processing

R_{31} = Cost rate for Down-transport weight

R_{41} = Cost rate for Ground mechanical handling operations (volume)

R_{42} = Cost rate for Ground electronics handling (data processing)

ATTACHMENT B

CANDIDATE COST POLICIES

POLICY

1. User should pay his fair share of Shuttle/Spacelab Resources:

    a) Up-transport costs based on weight and volume as a per cent of capacity.

    b) On-orbit costs based on energy, crew time, data transmission, and data processing used, as a per cent of capacity.

    c) Down-transport costs based on weight as a per cent of capacity.

    d) Ground mechanical and electronic operations costs based on size (volume) of payload handled and data processing (keyed to on-board experiment computer word storage) as a per cent of capacity.

2. Utilization factors and rates should be averaged over established time frames, reviewed regularly, and used to ensure allocation of all costs over a given time period.

3. Users who pre-empt a full mission by virtue of large volume, energy consumption, etc. should be charged on a case-by-case basis which recognizes the exclusion of other users.

ATTACHMENT C

EXAMPLE OF USER COST DETERMINATION

GEL Electrophoresis

	Allocated Costs ($)
Up-transport volume $V'' = 0.3M^3 \times \$13,760/M^3$	4.1K
Up-transport weight $W''_{12} = 65\text{ kg} \times \$108.81/\text{kg}$	7.1K
On-orbit energy $E''_{21} = 21.6\text{ KWH} \times \$1721/\text{KWH}$	37.2K
On-orbit crew support $S''_{22} = 11\text{ man hrs} \times \$6446/\text{hr}$	70.9K
On-orbit data transmission T''_{23} = (none)	-
On-orbit data processing $P''_{24} = 10\text{K words} \times \$2.36/\text{word}$	23.6K
Down-transport weight $W''_{31} = 65\text{ kg} \times \$184.44/\text{kg}$	12.0K
Mechanical ground operations $V'' = 0.3M^3 \times \$1,276/M^3$	0.4
Electronic ground operations $P''_{24} = 10\text{K words} \times \$20.89/\text{word}$	208.9K
Total Cost	$364.2K

SECTION IX

FINANCIAL MODEL USED FOR FINANCIAL ANALYSIS OF B.U.S. PHASE III BUSINESS VENTURE ASSESSMENT

Attached is a description of the financial analysis model which is being used for assessment of the viability of the 4 products under consideration in the Beneficial Uses of Space (BUS) Phase III Study (NAS 8-28179).

A brief description of the INVEST computer program which implements the same logic and adds present value and sensitivity calculations, is also attached.

In assembling the model contained herein, we sought opinions on the business factors to enter into the model. Key questions in that search are given in the attached questionaire.

FINANCIAL ANALYSIS MODEL (Figure 1)

The financial analysis model used is one designed for early assessment of business ventures which are in the conceptual phase (and hence are based on many assumptions and rough cost estimates) and which are sensitive to production volume, unit price and unit cost considerations. The routine for calculation is intentionally simplified so that manual exercises can be conducted if desired. Only six data entries are required:

- Total Market (unit demand, by year)
- Market Share (per cent, by year)
- Unit Price (in dollars, by year)
- Unit Manufacturing Cost (in dollars, by year)
- R&D Expense (in dollars, by year)
- Annual Plant and Equipment expenditures (in dollars, by year)

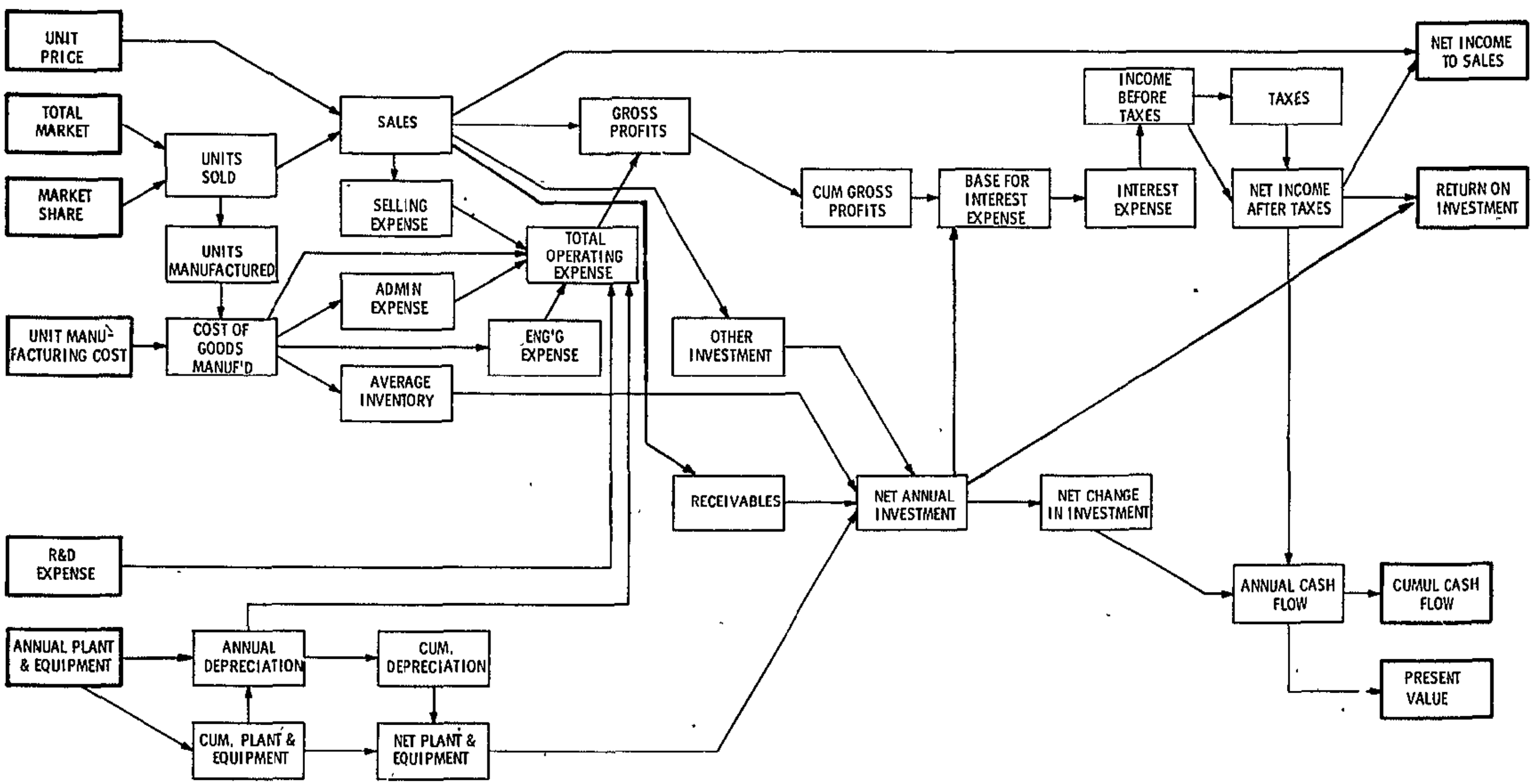


Figure 1. Financial Analysis Method for Assessment of Space Processing Opportunities

Calculation using simplified routines will then generate an informative time-phased forecast of 39 line items covering operating expense, investment and operating results, with the key indicators of per cent return on investment, per cent net income to sales, and cumulative cash flow. By examination of the time-phased data, the points can be determined at which annual cash flow turns positive, at which annual net income turns positive, and at which cumulative cash flow turns positive (payback or break even point). Also, the maximum negative cash flow and the year in which it occurs can be observed.

Where many iterations of the venture forecast are desired to examine sensitivity of assumptions, or to seek out more favorable cases, a computerized routine is used. The INVEST Program, (For Interactive New Venture Examination and Sensitivity Test) provides for punch card or keyboard input of the six data entries, CRT console display of operator routines, quick-look display of performance results for cases under study, and console variation of parameters. In addition to the routine forecast, the INVEST Program adds a calculation of present value, and a subroutine for sensitivity analysis whereby 9 parameters and the 6 data entries can be varied by a chosen percentage (e.g. $\pm$10%) to determine their effect on present value of the venture, and hence indicate the relative sensitivity of the venture to the values chosen for the parameters or data entries.

The forecast routine consists of three segments, Operating Results, Operating Expense and Investment. A brief description of the elements and calculations is given in the following paragraphs. The item numbers coincide with numerical identifiers used in the INVEST program.

OPERATING RESULTS

1. Total Market (Units)
   Total market (demand) is taken from the market forecast of units which could be sold annually over the forecast period (e.g. 1980 to 1992).

2. Market Share (Per Cent)

Market share is taken from the market forecast as a percent of the total market which the business entity would expect to satisfy.

3. Units Sold

The number of units sold is calculated as total market (units) times market share.

4. Unit Price

The unit price is taken from the market forecast as the price in each year of the forecast at which it is estimated the device could be sold in the quantities indicated by the Units Sold estimate.

5. Sales

Sales in dollars are calculated as the product of Units Sold times Unit Price.

6. Operating Expense

Operating expenses are incorporated in the Operating Results calculations to arrive at Gross Profits. The annual value of total operating expense used here is taken from the Operating Expense calculations (see No. 30).

7. Gross Profits

Gross profits are calculated for each year as the difference between annual sales dollars and annual operating expenses.

8. Annual Investment (Figure 2)

Annual investment is included in the Operating Results calculation to arrive at an approximate base for calculation of interest expense. The annual value of net annual investment is taken from the Investment calculations (see No.'s 31-39).

9. Cumulative Gross Profits

Cumulative gross profits are included in the Operating Results calculations as part of the determination of the base for interest expense. The amount is calculated as the cumulative total of annual gross profits to date, for each year.

10. Base for Interest Expense

The base for interest expense is calculated as the difference between the net annual investment and the cumulative gross profits. This presumes that the business uses its gross profits to finance its investment requirements and that any net annual investment which exceeds the cumulative gross profits requires external funds, which incur an interest expense. This method is a simplification of computer iterative techniques which are more exact. When cumulative gross profits exceed net annual investment, the base for interest expense is set at zero.

11. Interest Expense

Interest expense is calculated as a percentage of the annual base for interest expense. The baseline interest rate of 10% is reflective of the relatively high rates in 1975. Future rates may be lower.

12. Income Before Taxes

Income before taxes is calculated as annual Gross Profits less annual interest expense.

13. Federal Income Taxes

Federal income taxes are calculated as 48% of income before taxes.

14. Net Income After Taxes (Figure 3)

Net income after taxes is calculated as annual income before taxes less annual federal income taxes. Negative values are allowed on the basis that losses can be credited against other business income. The value calculated is before any payment of dividends to stockholders.

PER CENT RETURN ON INVESTMENT (ROI)

- A MEASURE OF BUSINESS PERFORMANCE IN TERMS OF OVERALL BUSINESS YIELD
- ANNUAL NET INCOME AFTER TAXES DIVIDED BY NET ANNUAL INVESTMENT (EXPRESSED AS A PER CENT)
- EXAMPLE: NET INCOME IN YEAR X = \$0.8M

  NET INVESTMENT IN YEAR X = \$5M

  $$\text{ROI} = \frac{\$0.8M}{\$5M} = .16 = 16\%$$

NET ANNUAL INVESTMENT

- THE SUM OF AVERAGE ACCOUNTS RECEIVABLE, INVENTORIES, AND DEPRECIATED PLANT & EQUIPMENT LESS AN ALLOWANCE FOR CERTAIN INVESTMENT-REDUCING LIABILITIES (ACCOUNTS PAYABLE, RESERVES, ETC)

Figure 2. Definitions of Financial Measures

PER CENT NET INCOME TO SALES (NI/S)

- A MEASURE OF BUSINESS PERFORMANCE RELATIVE TO INDUSTRY EXPECTATIONS
- ANNUAL NET INCOME AFTER TAXES DIVIDED BY ANNUAL SALES (EXPRESSED AS A PER CENT)
- EXAMPLE: SALES IN YEAR X = \$10M

  NET INCOME IN YEAR X = \$0.8M

  $$\text{NI/S} = \frac{\$0.8M}{\$10M} = .08 = 8\%$$

NET INCOME AFTER TAXES

- SALES REVENUE LESS OPERATING EXPENSE INTEREST EXPENSE, AND FEDERAL TAXES

Figure 3. Definitions of Financial Measures

15. Net Change in Investment

The net change in annual investment is included in the Operating Results calculation to determine annual cash flow. The amount is calculated by subtracting the previous year net annual investment from the current year value. This figure gives the increase or decrease in investment for the current year and hence affects cash flow.

16. Annual Cash Flow (Figure 4)

Annual cash flow or the amount of cash consumed or generated by the business, is calculated as the annual net income after taxes less the annual net change in investment. An increase (or decrease) in current year investment from the previous year will cause a negative (or positive) cash flow in that amount.

17. Cumulative Cash Flow (Figure 4)

The cumulative cash flow, which aggregates the annual cash requirements or surplus, is calculated as the summation of the annual cash flows from inception to current year for all the years in the forecast period.

18. Return on Investment (Figure 2)

The per cent return on investment, which is a measure of the overall yield of the business, is calculated as annual net income after taxes divided by net annual investment, and is given as a per cent.

19. Net Income to Sales (Figure 5)

The per cent net income to sales is calculated as annual net income after taxes divided by annual sales, and is given as a per cent.

CUMULATIVE CASH FLOW

- THE SUMMATION OF THE ANNUAL CASH FLOWS (INCOME LESS OUTGO) FROM INCEPTION TO CURRENT PERIOD, OVER THE CHOSEN FORECAST PERIOD

BREAKEVEN POINT

- THE POINT IN TIME AT WHICH THE CUMULATIVE CASH FLOW TURNS POSITIVE
- EXAMPLE:

  IN THE CUMULATIVE CASH FLOW EXAMPLE ABOVE, THE BREAKEVEN POINT IS 6 YEARS FROM START

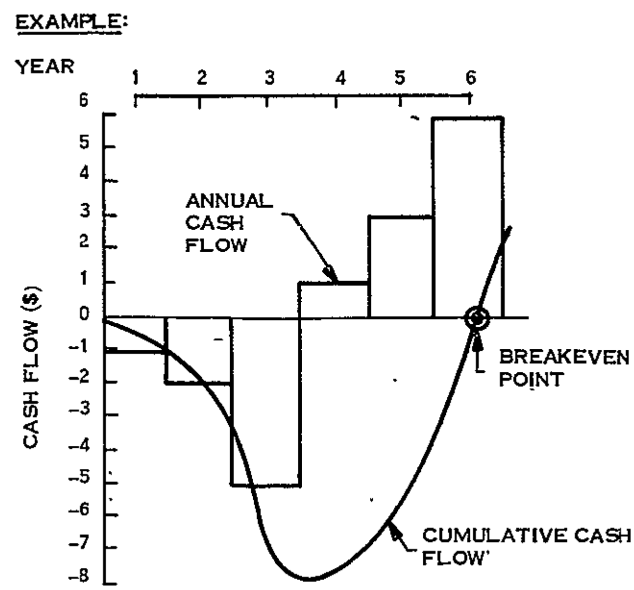


Figure 4. Definitions of Financial Measures

PRESENT VALUE

- A MEASURE OF THE VALUE TODAY OF FUNDS TO BE RECEIVED OR SPENT IN THE FUTURE (BASED ON A CHOSEN INTEREST OR DISCOUNT RATE)

$$\boxed{PV = \sum \frac{C_j}{(1+r)^j}}$$

WHERE j = 0, 1, 2, 3.... n YEARS

r = INTEREST RATE

C_j = FUNDS RECEIVED (+) OR SPENT (-) IN YEAR (j)

- EXAMPLE: WHAT IS THE PRESENT VALUE OF SPENDING \$100 3 YEARS FROM NOW AND RECEIVING A RETURN OF \$500 10 YEARS FROM NOW? (10% DISCOUNT)

$$\boxed{PV = \sum \frac{(-)\ \$100}{(1+.10)^2} + \frac{(+)\ \$500}{(1+.10)^9} = (+)\ \$129}$$

- COMPARE AN ALTERNATIVE OF SPENDING \$200 IN THE 2ND YEAR AND RECEIVING A RETURN OF \$600 IN THE 8TH YEAR (PV = (+) \$126)

Figure 5. Definitions of Financial Measures

19A. Present Value (Figure 5)

The present value (present worth) of the venture is a measure of the value today of funds to be received or spent in the future, based on a chosen interest or discount rate. The function used is the standard:

$$P = \frac{C_j}{(1 + r)^j}$$

where P = present value in dollars

C_j = annual cash flow in dollars

r = Interest rate (taken as 10%)

j = Year (first year = zero)

The present value measure can be used as a guide to determine whether the venture is more or less attractive than alternative investment opportunities.

OPERATING EXPENSE

20. Unit Manufacturing Cost

The unit manufacturing cost is taken from a cost estimate for each of the process steps required, including space processing. The space processing costs include an estimate of space charges for shuttle launch, in-orbit support and ground operations provided by NASA or an equivalent service organization. Costs have been estimated for an annual throughput which is in the range of the Units Sold value for the product in full-scale production. These annual costs divided by the nominal annual throughput gives the unit cost figure. No attempt has been made to adjust the unit manufacturing cost for other levels of operations, such as are encountered in the early years of operations.

21. Units Manufactured

The number of units manufactured is calculated as a percentage of units sold (e.g. 120%) to provide an approximate base for determination of annual in-process

and finished goods inventory. This is a simplified method. More exact methods would include separate estimates and data inputs for in-process and finished goods inventory, based on expected sales.

22. Cost of Goods Manufactured

The annual cost of goods manufactured in dollars is calculated as the product of unit manufacturing cost times the number of units manufactured.

23. Average Inventory

The average annual inventory in dollars is determined by the excess of units manufactured over the number of units sold, as given in Item 21. This inventory calculation is a simplified method which avoids estimation of beginning and ending inventories.

25. R&D Expense

The research and development expense is taken from the cost estimate and time profile for the research and development program which would achieve a prototype manufacturing capability for the product. Production start-up costs were not included.

If desired, the effects of these omitted costs can be assessed by general examination of the sensitivity of increased R&D cost on the present value of the venture.

26. Engineering Expense

Engineering expense in dollars is calculated as a percentage of the annual cost of goods manufactured.

27. Selling Expense

Selling expense in dollars is calculated as a percentage of annual sales.

28. Administration Expense

Administration expense in dollars is calculated as a percentage of the annual cost of goods manufactured.

29. Depreciation Expense

The annual value for depreciation expense is taken from the annual depreciation as determined in the Investment calculations. Depreciation expense is normally included in various overhead accounts such as engineering and manufacturing overhead, but is itemized separately here for assessment of impact.

30. Total Operating Expense

The annual total operating expense is calculated as the sum of the annual amounts for cost of goods manufactured, R&D expense, engineering expense, selling expense, administration expense, and depreciation expense. This value is used in the determination of Operating Results.

INVESTMENT

31. Receivables

Average annual receivables (accounts receivable) is calculated as a percentage of sales. This figure represents the funds tied up in goods shipped to customers, but not yet paid for. The baseline percentage of 20% reflects 10 weeks average delay in receipt of payment, which is a recent average for the General Electric Company.

32. Inventories

Average annual inventories is the same value as calculated for average annual inventory under Operating Expenses (See No. 23).

33. Annual Plant and Equipment Expenditures

Annual plant and equipment is taken from a time-phased cost estimate of plant and equipment items required for production, based on production level.

34. Cumulative Plant and Equipment Expenditures

Cumulative plant and equipment is calculated for each year as the summation from inception to current year of the annual plant and equipment expenditures. This figure is used for determination of annual net plant and equipment.

35. Annual Depreciation

Annual depreciation is effectively calculated via a depreciation schedule wherein each annual plant and equipment expenditure is depreciated on a straight line basis over a chosen number of years (depreciation period). For simplicity the chosen depreciation period (e.g., 10 years) is made applicable to all items on a common basis, regardless of type. If desired, the effect of the chosen depreciation period can be assessed by varying the period and examining the resulting performance of the venture. A more exact method would be to itemize the plant and equipment, establish individual depreciation periods and prepare a depreciation schedule based on this information.

36. Cumulative Depreciation

Cumulative depreciation is calculated for each year as the summation from inception to current year of the annual depreciation amounts. This figure is used for subsequent determination of annual net plant and equipment.

37. Net Plant and Equipment

Net plant and equipment (after adjustment for depreciation) is calculated for each year as cumulative plant and equipment less cumulative depreciation.

38. Other Investment (Average)

Other investment recognizes the funds held by the business which represent liabilities, such as accounts payable, reserves, and sundry creditor items. It is calculated as a percentage of sales and is a deduction when arriving at net annual investment.

39. Net Annual Investment

Net annual investment, which is a measure of the net fixed and current assets invested in the business, is calculated as the sum of average annual receivables, average annual inventories and annual net plant and equipment, less average other investment. This figure is used in the Operating Results calculations.

It is recognized that the calculated plant and equipment amount is a year-end value, rather than an average. The more exact method would be to take the average of beginning-of-year and end-of-year values.

INVEST

A PROGRAM FOR

INTERACTIVE NEW VENTURE EXAMINATION

AND

SENSITIVITY TEST

"INVEST" PROGRAM

INTERACTIVE NEW VENTURE EXAMINATION AND SENSITIVITY TEST

What It Is:

A CRT/Console Program for examining financial performance (up to 20 year forecast) of commercial production ventures.

What It Does:

	Now	Later
Calculates:	- Return on investment (%) - Net income to sales (%) - Cash flow - Present value (present worth) - Sensitivity of parameters	DCRR X-Y plots
Prints:	- Complete financial spread sheet of venture - Sensitivity plot data	
Displays:	- Interactive operator routine/options - Summary of business forecast (ROI, NI/S, Cum cash flow) - Sensitivity plot data	
Interacts:	Allows operator variation of: 6 Data Entries (Amount or Percentage Change) 9 Parameters (Percentage Change)	

SIMPLE INPUT (SAMPLE ENTRIES SHOWN)

(APPROX. ONE PUNCH CARD PER ITEM FOR 10-YEAR FORECAST)

(1)	Total Market (Units): (Up to 99,999,999)	T75	=	30,000, ETC.	T92 =	60,000
(2)	Market Share (%) (0-100%)	S75	=	50, ETC.	S92 =	55.
(3)	Unit Price ($) (Up to $9999.99)	PR75	=	9.10, ETC.	PR92 =	8.35
(4)	Unit Manuf. Cost ($) (Up to $9999.99)	C75	=	4.50, ETC.	C92 =	3.75
(5)	R&D Costs ($) (Up to $9999.999/yr)	R75	=	100,000, ETC.	R92 =	0
(6)	Plant & Equip. Costs ($) (Up to $9,999,999/yr)	Q75	=	0, ETC.	Q92 =	200,000

NO ENTRIES REQUIRED FOR YEARS WITH ZERO VALUES.

SAMPLE EXERCISE

BASED ON MY BASELINE BUSINESS ESTIMATE, CAN I MAKE MONEY?

(1) ENTER: (PUNCH CARDS OR KEYBOARD) (BASELINE BUSINESS ESTIMATE)

- Total Market Demand (Units by Year (1975-1992)
- Market Share (%) by Year
- Unit Price ($) by Year
- Unit Manuf. Cost ($) by Year
- R&D Costs ($) by Year
- Annual Plant & Equipment by Year

$\}$ 6 to 12 Punch Cards (10 to 20 Yrs)

(2) ON KEYBOARD:

HIT	7	(CR)	=	Data Base Initialization
	9	(CR)	=	Process Current Data
	10	(CR)	=	Enter Case Title (up to 24 characters)
	5	(CR)	=	Print Hard Copy (Prints complete spread sheet)
	or			
	4	(CR)	=	Display Results (Puts ROI, NI/S & Cum. Cash on CRT)

(3) READ FROM PRINTOUT: % Return on Investment (Annual)
% Net Income to Sales (Annual)
Annual Net Income
Max. Negative Cash Flow (by examination)
Cum. Cash Flow
Present Value
Annual Net Investment
Annual Sales
Etc.

SAMPLE EXERCISE

I DON'T LIKE THE RESULTS. WHAT IF I INCREASE MY MARKET SHARE?

(1) ON KEYBOARD:

HIT:	8	(CR)	=	Restore Data Base (If not at baseline)
	1	(CR)	=	Parameter Initialization (Standard or Perturb)
	2	(CR)	=	Parameter Perturbation
ENTER:				
		(CR)		Until Correct Parameter Shows Up
		X2	=	? <u>150</u> (CR) (Change Baseline Market Share to 150% of Baseline)
HIT:	9	(CR)	=	Process New Case (increased market share)
	4	(CR)	=	Display Results (New ROI, NI/S, CUM. Cash Flow)
	5	(CR)	=	Print Hard Copy (If you want a copy)

(2) REPEAT WITH CHANGE OF ANY PARAMETER OR INPUT UNTIL YOU GET WHAT YOU WANT (OR MAKE COMBINATIONS OF CHANGES).

OPERATOR CAN CHANGE ANY OF THE FOLLOWING:
(OPTION 2: INTERACTIVE PROCESSOR)

Input Values (Change by Fixed Amount in All Years or by %)		Parameters (Change by Percent, .00001% of Baseline (=Zero) or Higher)	
X1	Total Market (%) (Up to 9999%)	P11	= Interest Rate
A1	Total Market (Amount) (Any Number Within Total Market Limit)	P21	= Units Manufactured as % of Units Sold
X2	Market Share (%)	P23	= Avg. Inventory as % of Cost of Goods Manufactured
A2	Market Share (Amount)	P26	= Engineering Expense as % of Cost of Goods Manufactured
K3	Unit Price (%)	P27	= Selling Expense as % of Sales
A3	Unit Price (Amount)	P28	= Admin. Expense as % of Cost of Goods Manufactured
X4	Unit Mfg. Cost (%)	P31	= Receivables as % of Cost of Goods Shipped
A4	Unit Mfg. Cost (Amount)		
X5	R&D Cost (%)	P35	= Depreciation Period (Years)
A5	R&D Cost (Amount)	P38	= Other Investment as % of Sales
X6	Annual Plant & Equip. (%)		
A6	Annual Plant & Equip (Amount)		

Input Limits (Input Values)

- Any % up to 9999%, any amount within total item limit.

Input Limits (Parameters)

- Any figure from .00001 (= zero %) to 9999%.
- Deprec. Period = Any No. of Years (must be compatible with plant & equipment input).

SAMPLE EXERCISE

WHAT INPUT VALUES OR PARAMETERS HAVE THE GREATEST EFFECT ON PRESENT VALUE? (i.e. MOST SENSITIVE TO A CHANGE IN ESTIMATE) (OPTION 12: SENSITIVITY ANALYSIS)

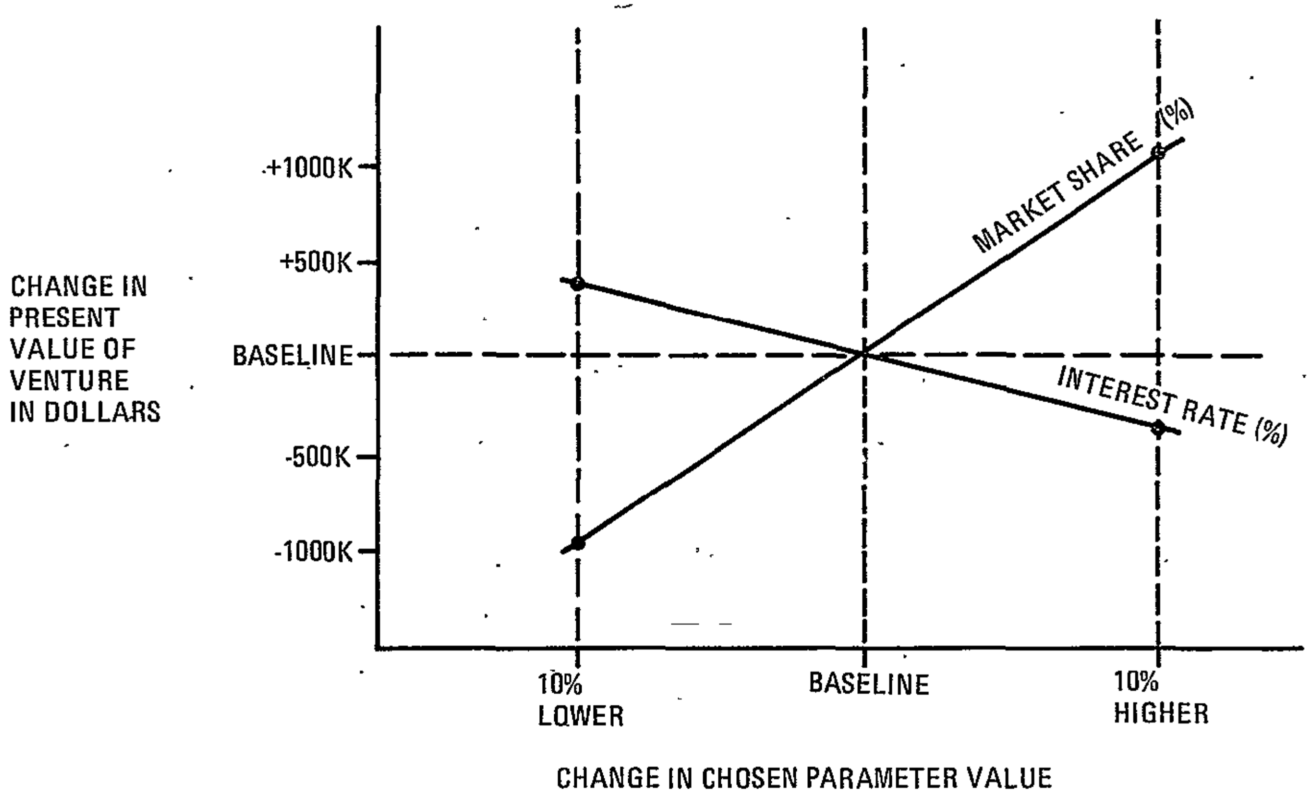
(1) ON KEYBOARD:

HIT:	8	(CR)	=	Restore Data Base
	5	(CR)	=	Print Hard Copy (Record Baseline Case)
	10	(CR)	=	Enter Case Identifier (e.g. "Sensitivity Analysis")
	12	(CR)	=	Calculate Sensitivities of 15 Factors
	4	(CR)	=	Display Results (10% Low, 10% High, Each Parameter in Terms of Present Value)

(2) Examine Display for factors With Large Ranges in Present Value For ±10% Variation.

(3) Automatic Printout of Results as Part of Step 12.

SENSITIVITY ANALYSIS
(PLOT OF PRINTOUT DATA)



BUSINESS ASSESSMENT QUESTIONNAIRE

PRODUCT ______________________

1. The following baseline factors have been suggested for the Business Analysis. For the type business involved, are these percentages appropriate, or can you suggest better factors?

Line No.	Factor	Baseline	Suggestion
27	Selling Expense	5% of Sales	________
28	Administrative Expense	10% of Sales	________
25	Depreciation Period	10 Years	________
26	Engineering Expense	5% of Cost of Goods Manuf'd	________
11	Annual Interest Rate	10%	________
31	Accts. Receivable	20% of Sales	________
32	Inventories	20% of Cost of Units Sold	________
38	Accts. Payable (Other Investment)	5% of Sales	________

2. In assessing this business opportunity, what lower limits would this business require, for the following business measures (in later years of production)?

Per cent Net Income to Sales ______________ %

Per cent Return on Investment ______________ %

3. Are there any other measures for assessing the attractiveness of the venture which you would use? If so, what are they?

4. Based on the financial forecast, are the following conditions acceptable (in your mind) for the candidate product venture? Can you suggest a better or minimum acceptable condition if you find any baseline conditions to be unacceptable?

   a) Date of first sales relative to start of research and development (R&D) effort. (Line 5)

b) Value of maximum negative annual cash flow. (Line 16)

c) Date of first positive annual cash flow relative to start of R&D effort. (Line 16)

d) Date of first positive cumulative cash flow relative to start of R&D effort (payback period). (Line 17)

5. Are the forecasts for the following items reasonable, as shown in the financial forecast?

   - Total Market (units) (Line 1)
   - Market Share (per cent) (Line 2)
   - Unit Price (dollars) (Line 4)
   - Unit Manufacturing Cost (dollars) (Line 20)
   - Annual Plant and Equipment (dollars) (Line 32)

6. How do you assess the overall opportunity that this venture presents to an entrepreneur? Would your company be interested in exploring or developing this opportunity? Do you think that some other company or type of company might be interested?

7. If you find the venture generally unattractive, can you suggest a basis on which your company or some other company might become interested?

GENERAL ELECTRIC

Space Division / Headquarters: Valley Forge, Pennsylvania ☐ Daytona Beach, Fla. ☐ Cape Kennedy, Fla. ☐ Evendale, Ohio ☐ Huntsville, Ala. ☐ Bay St. Louis, Miss. ☐ Houston, Texas ☐ Sunnyvale, Calif. ☐ Roslyn, Va. ☐ Beltsville, Md.